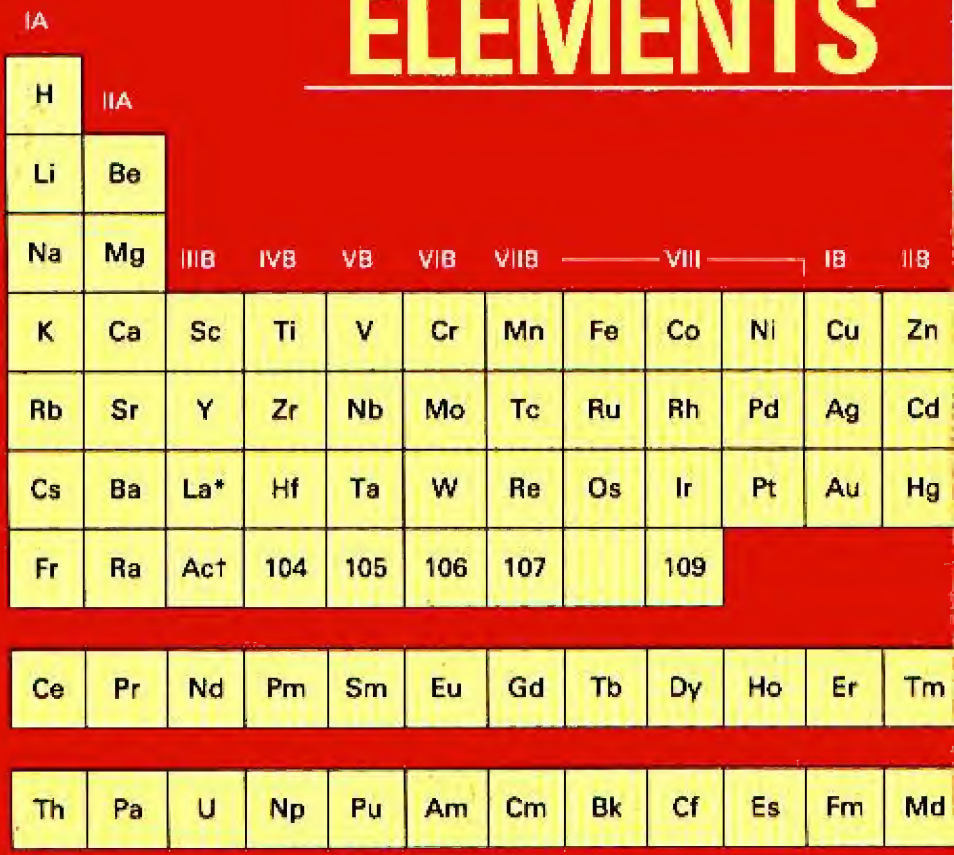
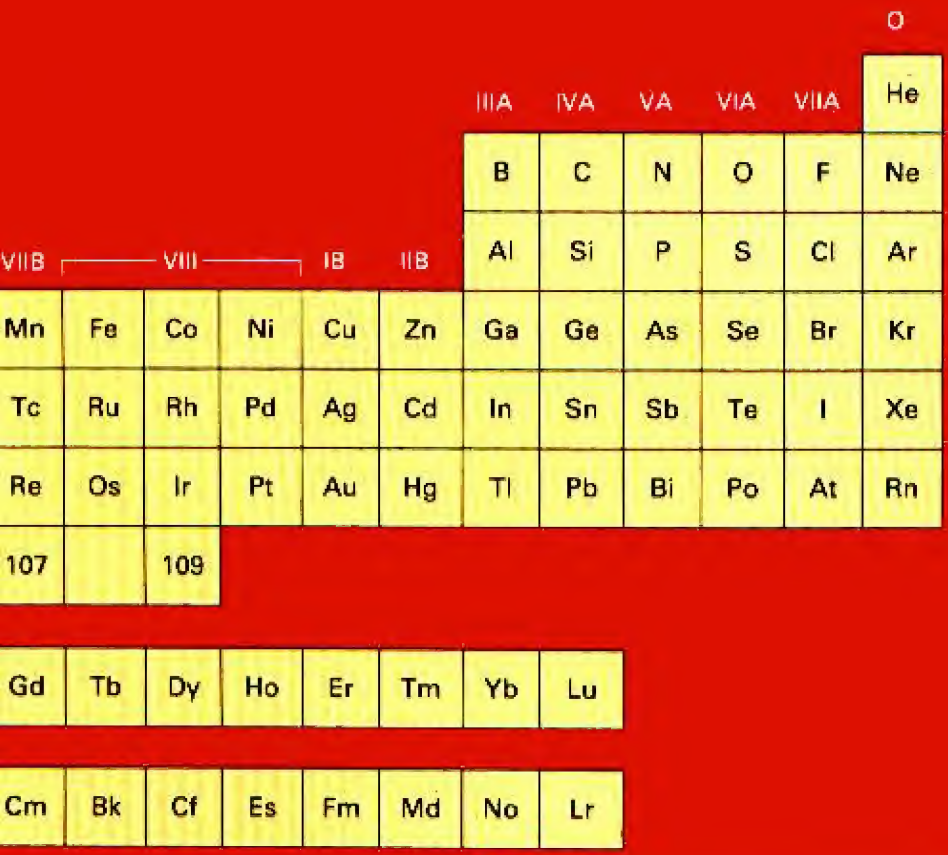
# HANDBOOK OF THE ELEMENTS




SAMUEL RUBEN

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# Handbook of the Elements

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Samuel Ruben

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# Preface

*Handbook of the Elements* is a practical reference source that provides essential information on the 108 known chemical elements for students and working scientists alike.

Knowledge about the elements is critical to our understanding of science and the world around us. This edition represents the most up-to-date compilation of information on the elements currently available.

Data on the chemical elements have been the fundamentals of scientific work for years, yet new research is continually revising previously published material about them. Even physical "constants" are subject to change in the light of additional research.

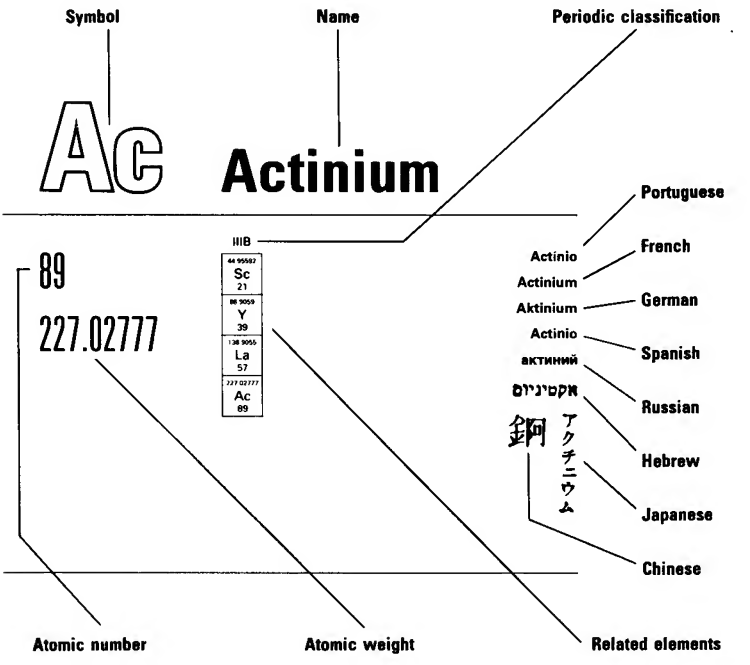
The information contained in this the third edition reflects state-of-the-art values on the most frequently required constants. The material in this current edition was compiled, corrected, and updated over a period of several years, utilizing hundreds of sources. Each value was checked in a minimum of 10 sources to ensure accuracy. A partial listing of the primary reference sources consulted is given at the end of the monographs.

I wish to acknowledge the significant assistance of Wayne Hruden for updating the reported values of the constants and the support given by the Duracell International Inc.

SAMUEL RUBEN
December 1984

# Introduction

This handbook contains monographs for each of the 108 known chemical elements, arranged in alphabetical order for rapid reference.




Except where unavailable, values for the following twenty-five different elemental constants are given:

**Periodic classification** The group, family name, and/or series of the element; this categorization reflects the position of the element in the periodic table.

**Atomic number** An element of atomic number $Z$ occupies the $Z$th position in the periodic classification. Its neutral atom has a nucleus with a charge of $+Ze$ surrounded by $Z$ electrons, each of charge $-e$.

**Atomic weight** The relative atomic mass ($A_r$) based on $^{12}C \equiv 12$; the value for the most stable isotope is given for synthetic elements.

**Naturally occurring isotopes** Mass numbers of the isotopes are listed in decreasing order of natural terrestrial abundance.

**Density** The weight per unit volume of the element; measurements of this constant are generally made at 25°C, but the temperature utilized is shown in parentheses. Units are grams per cubic centimeter ($g/cm^3$).

**Melting point** Units are degrees Celsius (°C); **Boiling point:** Units are degrees Celsius (°C).

**Latent heat of fusion** The quantity of heat required to change 1 g of the solid element into the liquid state at a constant temperature. Units are Joules per gram (J/g).

**Specific heat** The thermal capacity of an element; the specific heat capacity is the quantity of heat required to raise the temperature of a mass through a measured number of Celsius degrees. Units are Joules per gram per degree Celsius (J/g/°C).

**Coefficient of lineal thermal expansion** The ratio of the change in length per degree Celsius to the original length at zero degrees Celsius. Units are centimeter per centimeter per degree Celsius (cm/cm/°C).

**Thermal conductivity** Thermal energy transmitted through a unit cube per unit time when there exists unit temperature difference between opposite parallel faces. Units are watts (or milliwatts) per centimeter per degree Celsius [w (or mw)/cm/°C].

**Electrical resistivity** A proportionality factor ($\rho$) relating the resistance to current flow between parallel faces of a 1-cm cube of the element. This factor is also known as specific resistance. Because the resistance of semiconductor is substantially influenced by the presence of traces of impurities, the intrinsic resistivity is the parameter given for these ultrapure elements. Units are ohm-centimeters (ohm-cm).

**Ionization potential (1st)** The energy necessary to remove the least strongly bound electron from its orbit and place it at rest at an infinite distance. Units are electron volts (eV).

**Electron work function ($\phi$)** The minimum photonic energy required to remove an electron from the boundary of an element; also known as photoelectric work function. Units are electron volts (eV).

**Oxidation potential** The difference in potential produced by a voltaic half-cell associated with the cited chemical reaction. By using the oxidation potential, the likelihood of various chemical reactions can be predicted. Oxidation of gaseous hydrogen (at 1 atmosphere pressure) to ionic hydrogen (in 1 molar acid solution at 25°C) defines the zero reference. Units are volts (V).

**Chemical valence** The number of hydrogen atoms (or their equivalent) with which an atom of an element can combine (if negative) or the number which it can displace in a reaction (if positive). The principal valence is set in italic type when more than one valence is possible.

**Electrochemical equivalents** The mass of an element displaced by the passage of unit quantity of electricity. The values provided are derived from:

$$\text{electrochemical equivalents} = \frac{kA}{n}$$

where $k$ is a constant equal to 0.0373100, A is the gram-atomic weight, and $n$ is the principal valence. Units are grams per ampere-hour (g/amp-hr).

**Ionic radius** The radius an ion exhibits in an ionic crystal in which the ions are packed together with their outermost electronic shells in contact with each other. Values are given for a coordination number of 6. Ionic radii for other coordination numbers can be obtained by multiplying by the following conversion factors:

| *Coordination Number* | *Conversion Factor* |
|---|---|
| 12 | 1.12 |
| 9 | 1.05 |
| 8 | 1.03 |
| 6 | 1.00 |
| 4 | 0.94 |

Units are Ångstroms (1Å = $10^{-8}$ cm).

**Valence electron potential ($-\epsilon V$)** A calculated value based on the charge of the valence electrons and the ionic radius. It provides a quantitative indication of the reactivity of an element and is determined by the equation:

$$(-\epsilon V) = \frac{kn}{r}$$

where $(-\epsilon V)$ is the valence electron potential, $n$ is the valence, and $k$ is a proportionality factor converting Ångstroms to centimeters and expressing the force exerted by the valence electrons in electron volts and is equal to 14.399; $r$ is the ionic radius in Ångstroms. The principal valence has been used for the determination.

**Electronic configuration** A sequential listing of the orbiting electrons, indicating the principal shells and the number of electrons in each subshell. For example, $4d^{10}$ would indicate the presence of 10 electrons in the "d" subshell of the fourth (N) principal shell. Principal shells are assigned letters corresponding to their quantum numbers as follows: 1 = K, 2 = L, 3 = M, 4 = N, 5 = O, 6 = P, and 7 = Q. A maximum exists for the number of electrons in each subshell: 2 in s, 6 in p, 10 in d, and 14 in f.

**Valence electrons** A sequential listing of the electrons involved in the ionization of the element. They are indicated in the same manner as in the electronic configuration.

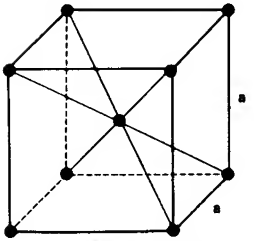
**Crystal form** A brief description of the atomic arrangement in the elemental solid state. (See accompanying figure for common Crystal Forms).

**Half life** The time required for one-half of an initial quantity of a radioactive isotope to be converted into its decay product. This entry is included only when all known isotopes of an element are unstable. The half life presented is that of the most stable isotope. Units are seconds, minutes, hours, days, or years.

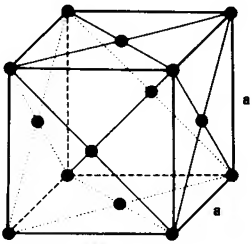
**Cross section $\sigma$** The effective size of a nucleus in capturing a thermal (slow) neutron. The larger the cross section the greater is the probability of neutron capture. Units are millibarns (mbarns) or barns (1 barn = $10^{-24}$ $cm^2$).

**Vapor pressure** The pressure exerted when a solid or liquid is in equilibrium with its vapor. Since this parameter is a function of temperature, the vapor pressure at the melting point is given. Units are Pascals (Pa).

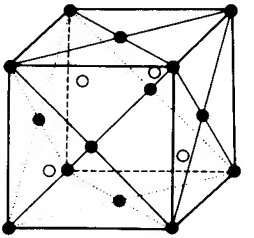
# Crystal Forms



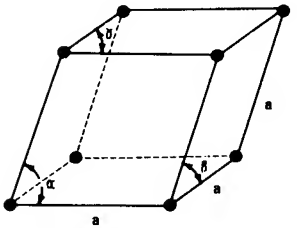

CUBIC, BODY CENTERED




CUBIC, FACE CENTERED

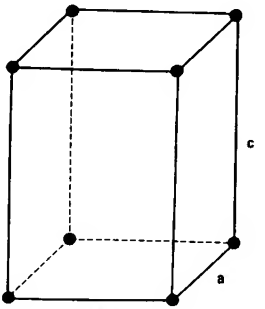


CUBIC, DIAMOND



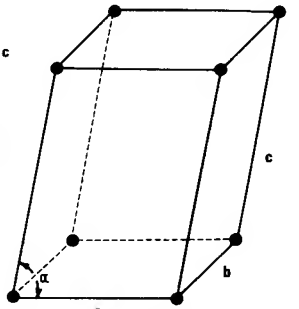

RHOMBOHEDRAL

α, β, γ, ≠ 90°



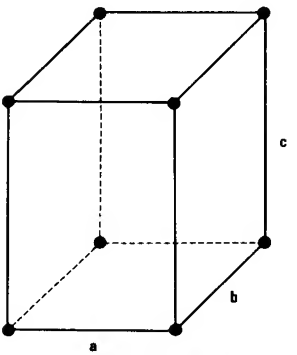

TETRAGONAL

a ≠ c



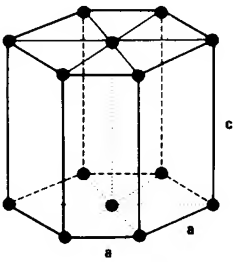

MONOCLINIC

α ≠ 90°




ORTHORHOMBIC

a ≠ b ≠ c




HEXAGONAL

a ≠ c

# Periodic Classification of the Elements

| IA | IIA | IIIB | IVB | VB | VIB | VIIB | VIII | VIII | VIII |
|---|---|---|---|---|---|---|---|---|---|
| 1.0079 H 1 | | | | | | | | | |
| 6.941 Li 3 | 9.01218 Be 4 | | | | | | | | |
| 22.98977 Na 11 | 24.305 Mg 12 | | | | | | | | |
| 39.098 K 19 | 40.08 Ca 20 | 44.95592 Sc 21 | 47.90 Ti 22 | 50.9415 V 23 | 51.996 Cr 24 | 54.9380 Mn 25 | 55.847 Fe 26 | 58.9332 Co 27 | 58.70 Ni 28 |
| 85.4678 Rb 37 | 87.62 Sr 38 | 88.9059 Y 39 | 91.22 Zr 40 | 92.9064 Nb 41 | 95.94 Mo 42 | 96.906 Tc 43 | 101.07 Ru 44 | 102.9055 Rh 45 | 106.4 Pd 46 |
| 132.9054 Cs 55 | 137.34 Ba 56 | 138.9055 La* 57 | 178.49 Hf 72 | 180.9479 Ta 73 | 183.85 W 74 | 186.2 Re 75 | 190.2 Os 76 | 192.22 Ir 77 | 195.09 Pt 78 |
| 223.01976 Fr 87 | 226.02544 Ra 88 | 227.02777 Act† 89 | 104 | 105 | 106 | 107 | | 109 | |

## *Lanthanide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 140.12 Ce 58 | 140.9077 Pr 59 | 144.24 Nd 60 | 144.913 Pm 61 | 150.4 Sm 62 | 151.96 Eu 63 | 157.25 Gd 64 | 158.9254 Tb 65 | 162.50 Dy 66 | 164.9304 Ho 67 |

## †Actinide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 232.03807 Th 90 | 231.0359 Pa 91 | 238.029 U 92 | 237.0482 Np 93 | 244.06423 Pu 94 | 243.0614 Am 95 | 247.07038 Cm 96 | 247.07032 Bk 97 | 251.07961 Cf 98 | 254.08805 Es 99 |

| | | | | | | | O |
|---|---|---|---|---|---|---|---|
| | | IIIA | IVA | VA | VIA | VIIA | 4.00260 He 2 |
| | | 10.81 B 5 | 12.011 C 6 | 14.0067 N 7 | 15.9994 O 8 | 18.998403 F 9 | 20.179 Ne 10 |
| | | 26.98154 Al 13 | 28.0855 Si 14 | 30.97376 P 15 | 32.06 S 16 | 35.453 Cl 17 | 39.948 Ar 18 |
| IB | IIB | | | | | | |
| 63.546 Cu 29 | 65.38 Zn 30 | 69.72 Ga 31 | 72.59 Ge 32 | 74.9216 As 33 | 78.96 Se 34 | 79.904 Br 35 | 83.80 Kr 36 |
| 107.868 Ag 47 | 112.41 Cd 48 | 114.82 In 49 | 118.69 Sn 50 | 121.75 Sb 51 | 127.60 Te 52 | 126.9045 I 53 | 131.30 Xe 54 |
| 196.9665 Au 79 | 200.59 Hg 80 | 204.37 Tl 81 | 207.2 Pb 82 | 208.9804 Bi 83 | 208.98243 Po 84 | 209.987 At 85 | 222.01761 Rn 86 |

| | | | |
|---|---|---|---|
| 167.26 Er 68 | 168.9342 Tm 69 | 173.04 Yb 70 | 174.97 Lu 71 |

| | | | |
|---|---|---|---|
| 257.09515 Fm 100 | 258 Md 101 | 259 No 102 | 260 Lr 103 |

# Ac Actinium

89

227.02777

IIIB

| 44.95592 |
|---|
| Sc |
| 21 |
| 88.9059 |
| Y |
| 39 |
| 138.9055 |
| La |
| 57 |
| 227.02777 |
| Ac |
| 89 |

Actínio
Actinium
Aktinium
Actinio
актиний
אקטיניום
錒 アクチニウム

**Naturally occurring isotope:** 227 (minute quantities only)
**Density:** 10.07 g/cm$^3$ (25°C)
**Melting point:** 1100 ± 50°C **Boiling point:** 3200 ± 300°C (est)
**Latent heat of fusion:** 62 J/g
**Specific heat:** 0.12 J/g/°C
**Thermal conductivity:** 0.12 w/cm/°C (25°C)
**Ionization potential (1st):** 5.17 eV
**Oxidation potential:** $Ac \rightarrow Ac^{3+} + 3\epsilon = 2.2$ V
**Chemical valence:** 3
**Electrochemical equivalents:** 2.82347 g/amp-hr
**Ionic radius:** 1.119 Å ($Ac^{3+}$)
**Valence electron potential (−ϵV):** 38.60 ($Ac^{3+}$)
**Principal quantum number:** 7
**Principal electron shells:** K L M N O P Q
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 6s^2\ 6p^6\ 6d^1\ 7s^2$
**Valence electrons:** $6d^1\ 7s^2$
**Crystal form:** Cubic, face centered
**Half life:** 21.77 years
**Cross section σ:** 810 ± 20 barns

# Al Aluminum

13

26.98154

IIIA

| 10.81 |
|---|
| B |
| 5 |
| 26.98154 |
| Al |
| 13 |
| 69.72 |
| Ga |
| 31 |
| 114.82 |
| In |
| 49 |
| 204.37 |
| Tl |
| 81 |

**Alumínio**
**Aluminium**
**Aluminium**
**Aluminio**
**алюминий**
**אלומין**
鉛 アルミニウム

**Naturally occurring isotope:** 27
**Density:** 2.6984 g/cm$^3$ (20°C)
**Melting point:** 660.37°C **Boiling point:** 2467°C
**Latent heat of fusion:** 395.7 J/g
**Specific heat:** 0.903 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 23.9 × 10$^6$cm/cm/°C (20°C)
**Thermal conductivity:** 2.37 w/cm/°C (25°C)
**Electrical resistivity:** 2.6548 × 10$^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 5.986 eV
**Electron work function $\phi$:** 4.28 eV
**Oxidation potential:** $Al \rightarrow Al^{3+} + 3\epsilon = 1.662$ V
**Chemical valence:** 3
**Electrochemical equivalents:** 0.33556 g/amp-hr
**Ionic radius:** 0.535 Å ($Al^{3+}$)
**Valence electron potential ($-\varepsilon$V):** 80.7
**Principal quantum number:** 3
**Principal electron shells:** K L M
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$
**Valence electrons:** $3s^2\ 3p^1$
**Crystal form:** Cubic, face centered
**Cross section $\sigma$:** 232 ± 3 mbarns
**Vapor pressure:** 2.42 × 10$^{-6}$ Pa (at melting point)

# Am Americium

95

243.0614

Actinide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 232.03807 Th 90 | 231.0359 Pa 91 | 238.029 U 92 | 237.0482 Np 93 | 244.06423 Pu 94 | 243.0614 Am 95 | 247.07038 Cm 96 | 247.07032 Bk 97 | 251.07961 Cf 98 | 254.08805 Es 99 |
| 257.09515 Fm 100 | 258 Md 101 | 259 No 102 | 260 Lr 103 | | | | | | |

Amerício
Américium
Amerizium
Americio
америций
אמריציום
鎇 アメリシウム

**Naturally occurring isotopes:** None
**Density:** 13.67 g/cm$^3$ (20°C)
**Melting point:** 1176°C **Boiling point:** 2011°C
**Ionization potential (1st):** 5.99 eV
**Oxidation potential:** $Am \rightarrow Am^{3+} + 3\epsilon = 2.32$ V
**Chemical valence:** 2, *3*, 4, 5, 6
**Electrochemical equivalents:** 3.0229 g/amp-hr
**Ionic radius:** 0.982 Å ($Am^{3+}$)
**Valence electron potential (−εV):** 44.0
**Principal quantum number:** 7
**Principal electron shells:** K L M N O P Q
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 5f^7\ 6s^2\ 6p^6\ 7s^2$
**Valence electrons:** $5f^7\ 7s^2$
**Crystal form:** Hexagonal
**Half life:** $7.32 \times 10^3$ years
**Cross section σ:** 180 ± 20 barns

# Sb Antimony

51

121.75

VA

| |
|---|
| 14.0067<br>N<br>7 |
| 30.97376<br>P<br>15 |
| 74.9216<br>As<br>33 |
| 121.75<br>Sb<br>51 |
| 208.9804<br>Bi<br>83 |

**Antimônio**
**Antimoine**
**Antimon**
**Antimonio**
**сурьма**
**אנטימון**
**銻 アンチモン**

**Naturally occurring isotopes:** 121, 123
**Density:** 6.691 g/cm$^3$ (20°C)
**Melting point:** 630.74°C **Boiling point:** 1750°C
**Latent heat of fusion:** 165.0 J/g
**Specific heat:** 0.207 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** $9.2 \times 10^{-6}$ cm/cm/°C (0°C)
**Thermal conductivity:** 0.244 w/cm/°C (25°C)
**Electrical resistivity:** $39 \times 10^{-6}$ ohm-cm (0°C)
**Ionization potential (1st):** 8.641 eV
**Electron work function $\phi$:** 4.55 eV
**Oxidation potential:** $2Sb + 3H_2O \rightarrow Sb_2O_3 + 6H^+ + 6\epsilon = -0.152$ V
**Chemical valence:** −3, 0, *3*, 5
**Electrochemical equivalents:** 1.5142 g/amp-hr
**Ionic radius:** 0.76 Å ($Sb^{3+}$)
**Valence electron potential ($-\varepsilon$V):** 57
**Principal quantum number:** 5
**Principal electron shells:** K L M N O
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 5s^2\ 5p^3$
**Valence electrons:** $5s^2\ 5p^3$
**Crystal form:** Rhombohedral
**Cross section $\sigma$:** $5 \pm 1$ barns
**Vapor pressure:** $2.49 \times 10^{-9}$ Pa (at melting point)

# Ar Argon

18

39.948

O

| |
|---|
| 4.00260 He 2 |
| 20.179 Ne 10 |
| 39.948 Ar 18 |
| 83.80 Kr 36 |
| 131.30 Xe 54 |
| 222.01761 Rn 86 |

Argônio
Argon
Argon
Argón
аргон
ארגון
氩 アルゴン

**Naturally occurring isotopes:** 40, 36, 38
**Density:** 1.65 g/cm$^3$ (−233°C), 1.784 × 10$^{-3}$ g/cm$^3$ (0°C)
**Melting point:** −189.2°C **Boiling point:** −185.7°C
**Latent heat of fusion:** 29.45 J/g
**Specific heat:** 0.52032 J/g/°C (25°C)
**Thermal conductivity:** 0.1772 mw/cm/°C (27°C at 1 atm)
**Ionization potential (1st):** 15.759 eV
**Chemical valence:** 0
**Principal quantum number:** 3
**Principal electron shells:** K L M
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$
**Valence electrons:** ($3s^2\ 3p^6$)
**Crystal form:** Cubic, face centered
**Cross section σ:** 0.66 barns

# As Arsenic

33

74.9216

VA

| |
|---|
| 14.0067 N 7 |
| 30.97376 P 15 |
| 74.9216 As 33 |
| 121.75 Sb 51 |
| 208.9804 Bi 83 |

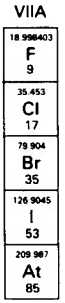
**Arsênio**
**Arsenic**
**Arsen**
**Arsénico**
**мышьяк**
**ארסן**
砷 砒素

**Naturally occurring isotope:** 75
**Density:** 5.73 g/cm$^3$ (gray) (20°C)
**Melting point:** 817°C (at 28 atm) **Boiling point:** 613°C (sublimes)
**Latent heat of fusion:** 369.9 J/g
**Specific heat:** 0.329 J/g/°C (gray) (25°C)
**Coefficient of lineal thermal expansion:** 6.02 × $10^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 0.502 w/cm/°C (gray) (25°C)
**Electrical resistivity:** 35 × $10^{-6}$ ohm-cm (0°C)
**Ionization potential (1st):** 9.81 eV
**Electron work function $\phi$:** 3.75 eV
**Oxidation potential:** $As + 2H_2O \rightarrow HAsO_2 + 3H^+ + 3\epsilon = -0.2476$ V
**Chemical valence:** −3, 0, *3*, 5
**Electrochemical equivalents:** 0.93177 g/amp-hr
**Ionic radius:** 0.58 Å ($As^{3+}$)
**Valence electron potential (−εV):** 74
**Principal quantum number:** 4
**Principal electron shells:** K L M N
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^3$
**Valence electrons:** $4s^2\ 4p^3$
**Crystal form:** Rhombohedral
**Cross section $\sigma$:** 4.30 ± 0.10 barns

# At Astatine

85

209.987




**Astato**
**Astatine**
**Astat**
**Astatino**
**астатин**
**אסטטין**
砹 アスタチン

**Naturally occurring isotopes:** None
**Melting point:** 302°C (est) **Boiling point:** 337°C (est)
**Latent heat of fusion:** 114 J/g (est)
**Ionization potential (1st):** 9.65 eV
**Oxidation potential:** $2At^- \rightarrow At_2 + 2\epsilon = -0.2$ V
**Chemical valence:** *1,* 3, 5, 7
**Electrochemical equivalents:** 7.8346 g/amp-hr
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 6s^2\ 6p^5$
**Valence electrons:** $6s^2\ 6p^5$
**Half life:** 8.1 hr

# Ba Barium

56

137.34

IIA

| |
|---|
| 9.01218<br>Be<br>4 |
| 24.305<br>Mg<br>12 |
| 40.08<br>Ca<br>20 |
| 87.62<br>Sr<br>38 |
| 137.34<br>Ba<br>56 |
| 226.02544<br>Ra<br>88 |

**Bário**
**Barium**
**Barium**
**Bario**
**барий**
**בריום**
銀 バリウム

**Naturally occurring isotopes:** 138, 137, 136, 135, 134, 130, 132
**Density:** 3.59 g/cm$^3$ (20°C)
**Melting point:** 725°C **Boiling point:** 1640°C
**Latent heat of fusion:** 55.79 J/g
**Specific heat:** 0.204 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 19.0 $\times$ 10$^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 0.184 w/cm/°C (22°C)
**Ionization potential (1st):** 5.212 eV
**Electron work function $\phi$:** 2.7 eV
**Oxidation potential:** $Ba \rightarrow Ba^{2+} + 2\epsilon = 2.906$ V
**Chemical valence:** 2
**Electrochemical equivalents:** 2.5621 g/amp-hr
**Ionic radius:** 1.35 Å ($Ba^{2+}$)
**Valence electron potential ($-\varepsilon V$):** 21.3
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 5s^2\ 5p^6\ 6s^2$
**Valence electrons:** $6s^2$
**Crystal form:** Cubic, body centered
**Cross section $\sigma$:** 1.2 $\pm$ 0.1 barns
**Vapor pressure:** 9.80 $\times$ 10 Pa (at melting point)

# Bk Berkelium

97

247.07032

Actinide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 232.03807 Th 90 | 231.0359 Pa 91 | 238.029 U 92 | 237.0482 Np 93 | 244.06423 Pu 94 | 243.0614 Am 95 | 247.07038 Cm 96 | 247.07032 Bk 97 | 251.07961 Cf 98 | 254.08805 Es 99 |
| 257.09515 Fm 100 | 258 Md 101 | 259 No 102 | 260 Lr 103 | | | | | | |

**Berquélio**
**Berkelium**
**Berkelium**
**Berkelio**
**беркелий**
**ברקליום**
**錇 バークリウム**

**Naturally occurring isotopes:** None
**Density:** 14.78 g/cm$^3$ (25°C)
**Melting point:** 986 ± 25°C
**Ionization potential (1st):** 6.23 eV
**Oxidation potential:** $Bk \rightarrow Bk^{3+} + 3\epsilon = 1.97$ V
**Chemical valence:** *3*, 4
**Electrochemical equivalents:** 3.0727 g/amp-hr
**Ionic radius:** 0.949 Å ($Bk^{3+}$)
**Valence electron potential (−εV):** 45.5
**Principal quantum number:** 7
**Principal electron shells:** K L M N O P Q
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 5f^8\ 6s^2\ 6p^6\ 6d^1\ 7s^2$
**Valence electrons:** $5f^8\ 6d^1\ 7s^2$
**Crystal form:** Hexagonal
**Half life:** $1.4 \times 10^3$ years

# Be Beryllium

4

9.01218

IIA

| |
|---|
| 9.01218<br>Be<br>4 |
| 24.305<br>Mg<br>12 |
| 40.08<br>Ca<br>20 |
| 87.62<br>Sr<br>38 |
| 137.34<br>Ba<br>56 |
| 226.02544<br>Ra<br>88 |

**Berílio**
**Beryllium**
**Beryllium**
**Berilio**
**бериллий**
**בריליום**
**鈹 ベリリウム**

**Naturally occurring isotope:** 9
**Density:** 1.848 g/cm$^3$ (20°C)
**Melting point:** 1278 ± 5°C **Boiling point:** 2970°C
**Latent heat of fusion:** 1301 J/g
**Specific heat:** 1.82 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 11.6 × $10^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 2.01 w/cm/°C (25°C)
**Electrical resistivity:** 4.0 × $10^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 9.322 eV
**Electron work function $\phi$:** 4.98 eV
**Oxidation potential:** $Be \rightarrow Be^{2+} + 2\epsilon = 1.85$ V
**Chemical valence:** 2
**Electrochemical equivalents:** 0.16812 g/amp-hr
**Ionic radius:** 0.35 Å ($Be^{2+}$)
**Valence electron potential ($-\varepsilon$V):** 82
**Principal quantum number:** 2
**Principal electron shells:** K L
**Electronic configuration:** $1s^2\ 2s^2$
**Valence electrons:** $2s^2$
**Crystal form:** Hexagonal, close packed
**Cross section $\sigma$:** 9.2 ± 0.5 mbarns
**Vapor pressure:** 4.18 Pa (at melting point)

# Bi Bismuth

83

208.9804

VA

| |
|---|
| 14.0067 N 7 |
| 30.97376 P 15 |
| 74.9216 As 33 |
| 121.75 Sb 51 |
| 208.9804 Bi 83 |

Bismuto
Bismuth
Wismut
Bismuto
висмут
ביומוט
鉍 ビスマス

**Naturally occurring isotope:** 209
**Density:** 9.78 g/cm$^3$ (20°C)
**Melting point:** 271.3°C **Boiling point:** 1560 ± 5°C
**Latent heat of fusion:** 52.09 J/g
**Specific heat:** 0.122 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 13.3 × $10^{-6}$ cm/cm/°C
**Thermal conductivity:** 0.0792 w/cm/°C (25°C)
**Electrical resistivity:** 106.8 × $10^{-6}$ ohm-cm (0°C)
**Ionization potential (1st):** 7.289 eV
**Electron work function** $\phi$**:** 4.22 eV
**Oxidation potential:** $Bi + H_2O \rightarrow BiO^+ + 2H^+ + 3\epsilon = -0.320$ V
**Chemical valence:** *3,* 5
**Electrochemical equivalents:** 2.5990 g/amp-hr
**Ionic radius:** 1.03 Å ($Bi^{3+}$)
**Valence electron potential (**$-\varepsilon$**V):** 41.9
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 6s^2\ 6p^3$
**Valence electrons:** $6s^2\ 6p^3$
**Crystal form:** Rhombohedral
**Cross section** $\sigma$**:** 19 ± 2 mbarns
**Vapor pressure:** 6.27 × $10^{-4}$ Pa (at melting point)

# Boron

5

10.81

IIIA

| 10.81 |
|---|
| B |
| 5 |
| 26.98154 |
| Al |
| 13 |
| 69.72 |
| Ga |
| 31 |
| 114.82 |
| In |
| 49 |
| 204.37 |
| Tl |
| 81 |

**Bóro**
**Bore**
**Bor**
**Boro**
**бор**
**בור**
硼 素

**Naturally occurring isotopes:** 11, 10
**Density:** 2.34 g/cm$^3$ (crystalline), 2.37 g/cm$^3$ (amorphous) (both at 20°C)
**Melting point:** 2300°C **Boiling point:** 2550°C (sublimes)
**Latent heat of fusion:** 890.8 J/g
**Specific heat:** 1.03 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** $8.3 \times 10^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 0.274 w/cm/°C (25°C)
**Electrical resistivity:** $1.8 \times 10^6$ ohm-cm (0°C)
**Ionization potential (1st):** 8.298 eV
**Electron work function $\phi$:** 4.45 eV
**Oxidation potential:** $B + 3H_2O \rightarrow H_3BO_3 + 3H^+ + 3\epsilon = -0.8698$ V
**Chemical valence:** 3
**Electrochemical equivalents:** 0.1344 g/amp-hr
**Ionic radius:** 0.23 Å ($B^{3+}$)
**Valence electron potential ($-\varepsilon$V):** 190
**Principal quantum number:** 2
**Principal electron shells:** K L
**Electronic configuration:** $1s^2\ 2s^2\ 2p^1$
**Valence electrons:** $2s^2\ 2p^1$
**Crystal form:** Hexagonal, close packed
**Cross section $\sigma$:** 759 barns
**Vapor pressure:** $3.48 \times 10^{-1}$ Pa (at melting point)

# Br Bromine

35

79.904

VIIA

| |
|---|
| 18.998403 F 9 |
| 35.453 Cl 17 |
| 79.904 Br 35 |
| 126.9045 I 53 |
| 209.987 At 85 |

**Bromo**
**Brome**
**Brom**
**Bromo**
**бром**
**ברום**
溴 臭素

**Naturally occurring isotopes:** 79, 81
**Density:** 3.1028 g/cm$^3$ (20°C)
**Melting point:** −7.2°C **Boiling point:** 58.78°C
**Latent heat of fusion:** 132.0 J/g ($Br_2$)
**Specific heat:** 0.47362 J/g/°C ($Br_2$) (25°C)
**Thermal conductivity:** 1.22 mw/cm/°C (27°C)
**Electrical resistivity:** 7.8 × 10$^{12}$ ohm-cm (0°C)
**Ionization potential (1st):** 11.814 eV
**Oxidation potential:** $2Br^- \rightarrow Br_2 + 2\epsilon = -1.0652$ V
**Chemical valence:** *−1*, 3, 5, 7
**Electrochemical equivalents:** 2.9812 g/amp-hr
**Ionic radius:** 1.96 Å ($Br^-$)
**Valence electron potential (−εV):** −7.35
**Principal quantum number:** 4
**Principal electron shells:** K L M N
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^5$
**Valence electrons:** $4s^2\ 4p^5$
**Crystal form:** Orthorhombic, rhombic
**Cross section σ:** 6.8 ± 0.1 barns
**Vapor pressure:** 5.80 × 10$^3$ Pa (at melting point)

# Cd Cadmium

48

112.41

IIB

| 65.38 |
|---|
| Zn |
| 30 |
| 112.41 |
| Cd |
| 48 |
| 200.59 |
| Hg |
| 80 |

Cádmio
Cadmium
Cadmium
Cadmio
кадмий
קדמיום
カドミウム

**Naturally occurring isotopes:** 114, 112, 111, 110, 113, 116, 106, 108
**Density:** 8.65 g/cm$^3$ (20°C)
**Melting point:** 320.9°C **Boiling point:** 765°C
**Latent heat of fusion:** 54.01 J/g
**Specific heat:** 0.231 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 29.8 $\times$ 10$^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 0.969 w/cm/°C (25°C)
**Electrical resistivity:** 6.83 $\times$ 10$^{-6}$ ohm-cm (0°C)
**Ionization potential (1st):** 8.993 eV
**Electron work function $\phi$:** 4.22 eV
**Oxidation potential:** $Cd \rightarrow Cd^{2+} + 2\epsilon = 0.4029$ V
**Chemical valence:** 2
**Electrochemical equivalents:** 2.0970 g/amp-hr
**Ionic radius:** 0.97 Å ($Cd^{2+}$)
**Valence electron potential ($-\varepsilon$V):** 30
**Principal quantum number:** 5
**Principal electron shells:** K L M N O
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 5s^2$
**Valence electrons:** $5s^2$
**Crystal form:** Hexagonal, close packed
**Cross section $\sigma$:** 2450 $\pm$ 20 barns
**Vapor pressure:** 1.48 $\times$ 10 Pa (at melting point)

# Ca Calcium

20

40.08

IIA

| |
|---|
| 9.01218 Be 4 |
| 24.305 Mg 12 |
| 40.08 Ca 20 |
| 87.62 Sr 38 |
| 137.34 Ba 56 |
| 226.02544 Ra 88 |

**Cálcio**
**Calcium**
**Kalzium**
**Calcio**
**кальций**
**סידן**
鈣 カルシウム

**Naturally occurring isotopes:** 40, 44, 42, 48, 43, 46
**Density:** 1.55 g/cm$^3$ (20°C)
**Melting point:** 839 ± 2°C **Boiling point:** 1484°C
**Latent heat of fusion:** 216.2 J/g
**Specific heat:** 0.632 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 22.3 × $10^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 2.01 w/cm/°C (25°C)
**Electrical resistivity:** 3.91 × $10^{-6}$ ohm-cm (0°C)
**Ionization potential (1st):** 6.113 eV
**Electron work function $\phi$:** 2.87 eV
**Oxidation potential:** $Ca \rightarrow Ca^{2+} + 2\epsilon = 2.866$ V
**Chemical valence:** 2
**Electrochemical equivalents:** 0.7477 g/amp-hr
**Ionic radius:** 0.99 Å ($Ca^{2+}$)
**Valence electron potential ($-\varepsilon$V):** 29
**Principal quantum number:** 4
**Principal electron shells:** K L M N
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$
**Valence electrons:** $4s^2$
**Crystal form:** Cubic, face centered
**Cross section $\sigma$:** 0.44 ± 0.02 barns
**Vapor pressure:** 2.54 × $10^2$ Pa (at melting point)

# Cf Californium

98

251.07961

Actinide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 232.03807 Th 90 | 231.0359 Pa 91 | 238.029 U 92 | 237.0482 Np 93 | 244.06423 Pu 94 | 243.0614 Am 95 | 247.07038 Cm 96 | 247.07032 Bk 97 | 251.07961 Cf 98 | 254.08805 Es 99 |
| 257.09515 Fm 100 | 258 Md 101 | 259 No 102 | 260 Lr 103 | | | | | | |

**Californio**
**Californium**
**Californium**
**Californio**
**калифорний**
**קליפורניום**
**鉲** カリフォルニウム

**Naturally occurring isotopes:** None
**Density:** 15.1 g/cm$^3$ (25°C)
**Melting point:** 900 ± 30°C
**Ionization potential (1st):** 6.30 eV
**Oxidation potential:** $Cf \rightarrow Cf^{3+} + 3\epsilon = 2.0$ V
**Chemical valence:** 2, *3,* 4
**Electrochemical equivalents:** 3.1226 g/amp-hr
**Ionic radius:** 0.934 Å ($Cf^{3+}$)
**Valence electron potential (−εV):** 44.5
**Principal quantum number:** 7
**Principal electron shells:** K L M N O P Q
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 5f^{10}\ 6s^2\ 6p^6\ 7s^2$
**Valence electrons:** $5f^{10}\ 7s^2$
**Crystal form:** Hexagonal
**Half life:** 900 years
**Cross section σ:** 2100 ± 1000 barns

# C Carbon

6

12.011

IVA

| |
|---|
| 12.011 C 6 |
| 28.0855 Si 14 |
| 72.59 Ge 32 |
| 118.69 Sn 50 |
| 207.2 Pb 82 |

**Carbono**
**Carbone**
**Kohlenstoff**
**Carbono**
**углерод**
**פחמן**
碳 炭素

**Naturally occurring isotopes:** 12, 13, 14
**Density:** 3.52 g/cm$^3$ (diamond), 1.9–2.3 g/cm$^3$ (graphite), 1.8–2.1 g/cm$^3$ (amorphous) (all at 20°C)
**Melting point:** 3550°C **Boiling point:** 4827°C
**Specific heat:** 0.7099 J/g/°C (graphite) (25°C)
**Coefficient of lineal thermal expansion:** $2.10 \times 10^{-6}$ cm/cm/°C (graphite) (30°C)
**Thermal conductivity:** 0.8–2.2 w/cm/°C (graphite) (25°C)
**Electrical resistivity:** $1375 \times 10^{-6}$ ohm-cm (graphite) (0°C)
**Ionization potential (1st):** 11.260 eV
**Electron work function $\phi$:** 5.0 eV
**Oxidation potential:** $CH_4 \rightarrow C + 4H^+ + 4\epsilon = -0.1316$ V
**Chemical valence:** 2, 3, *4*
**Electrochemical equivalents:** 0.11203 g/amp-hr
**Ionic radius:** 0.16 Å ($C^{4+}$)
**Valence electron potential ($-\varepsilon$V):** 360
**Principal quantum number:** 2
**Principal electron shells:** K L
**Electronic configuration:** $1s^2\ 2s^2\ 2p^2$
**Valence electrons:** $2s^2\ 2p^2$
**Crystal form:** Hexagonal (graphite), cubic (diamond)
**Cross section $\sigma$:** $3.4 \pm 0.2$ mbarns

# Ce Cerium

58

140.12

Lanthanide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 140.12 Ce 58 | 140.9077 Pr 59 | 144.24 Nd 60 | 144.913 Pm 61 | 150.4 Sm 62 | 151.96 Eu 63 | 157.25 Gd 64 | 158.9254 Tb 65 | 162.50 Dy 66 | 164.9304 Ho 67 |
| 167.26 Er 68 | 168.9342 Tm 69 | 173.04 Yb 70 | 174.97 Lu 71 | | | | | | |

**Cério**
**Cérium**
**Zerium**
**Cerio**
**церий**
**צריום**
铈 セリウム

**Naturally occurring isotopes:** 140, 142, 138, 136
**Density:** 6.657 g/cm$^3$ (25°C)
**Melting point:** 799°C **Boiling point:** 3426°C
**Latent heat of fusion:** 65.7 J/g
**Specific heat:** 0.192 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 7.1 $\times$ 10$^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 0.113 w/cm/°C (25°C)
**Electrical resistivity:** 77 $\times$ 10$^{-6}$ ohm-cm (25°C)
**Ionization potential (1st):** 5.47 eV
**Electron work function $\phi$:** 2.84 eV
**Oxidation potential:** Ce $\rightarrow$ Ce$^{3+}$ + 3$\epsilon$ = 2.483 V
**Chemical valence:** *3,* 4
**Electrochemical equivalents:** 1.7426 g/amp-hr
**Ionic radius:** 1.034 Å (Ce$^{3+}$)
**Valence electron potential (−$\varepsilon$V):** 41.78
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** 1s$^2$ 2s$^2$ 2p$^6$ 3s$^2$ 3p$^6$ 3d$^{10}$ 4s$^2$ 4p$^6$ 4d$^{10}$ 4f$^2$ 5s$^2$ 5p$^6$ 6s$^2$
**Valence electrons:** 4f$^2$ 6s$^2$
**Crystal form:** Cubic, face centered
**Cross section $\sigma$:** 0.73 ± 0.08 barns

# Cs Cesium

55

132.9054

IA

| |
|---|
| 1.0079 H 1 |
| 6.941 Li 3 |
| 22.98977 Na 11 |
| 39.098 K 19 |
| 85.4678 Rb 37 |
| 132.9054 Cs 55 |
| 223.0197 Fr 87 |

**Césio**
**Césium**
**Caesium**
**Ceslo**
**цезий**
**צזיום**
銫 セシウム

**Naturally occurring isotope:** 133
**Density:** 1.873 g/cm$^3$ (20°C)
**Melting point:** 28.40 ± 0.01°C **Boiling point:** 669.3°C
**Latent heat of fusion:** 16.372 J/g
**Specific heat:** 0.241 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 97 × 10$^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 0.359 w/cm/°C (solid at melting point)
**Electrical resistivity:** 20.46 × 10$^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 3.894 eV
**Electron work function** $\phi$**:** 2.14 eV
**Oxidation potential:** $Cs \rightarrow Cs^+ + \epsilon = 2.923$ V
**Chemical valence:** 1
**Electrochemical equivalents:** 4.95870 g/amp-hr
**Ionic radius:** 1.67 Å ($Cs^+$)
**Valence electron potential (**$-\varepsilon$**V):** 8.62
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 5s^2\ 5p^6\ 6s^1$
**Valence electrons:** $6s^1$
**Crystal form:** Cubic, body centered
**Cross section** $\sigma$**:** 30.0 ± 1.5 barns
**Vapor pressure:** 2.50 × 10$^{-5}$ Pa (at melting point)

# Cl Chlorine

17

35.453

VIIA

| |
|---|
| 18.998403<br>F<br>9 |
| 35.453<br>Cl<br>17 |
| 79.904<br>Br<br>35 |
| 126.9045<br>I<br>53 |
| 209.987<br>At<br>85 |

Clóro
Chlore
Chlor
Cloro
χлор
כלור
氯 塩素

**Naturally occurring isotopes:** 35, 37
**Density:** 1.56 g/cm$^3$ (−33.6°C), 3.214 × 10$^{-3}$ g/cm$^3$ (0°C)
**Melting point:** −100.98°C **Boiling point:** −34.6°C
**Latent heat of fusion:** 180.8 J/g ($Cl_2$)
**Specific heat:** 0.4782 J/g/°C ($Cl_2$) (25°C)
**Thermal conductivity:** 0.089 mw/cm/°C (27°C at 1 atm)
**Ionization potential (1st):** 12.967 eV
**Oxidation potential:** $2Cl^- \rightarrow Cl_2 + 2\epsilon = -1.3595$ V
**Chemical valence:** −*I*, 3, 5, 7
**Electrochemical equivalents:** 1.3228 g/amp-hr
**Ionic radius:** 1.81 Å ($Cl^-$)
**Valence electron potential (−εV):** −7.96
**Principal quantum number:** 3
**Principal electron shells:** K L M
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$
**Valence electrons:** $3s^2\ 3p^5$
**Crystal form:** Tetragonal
**Cross section σ:** 33 barns
**Vapor pressure:** 1.30 × 10$^3$ Pa (at melting point)

# Cr Chromium

24

51.996

VIB

| |
|---|
| 51.996 Cr 24 |
| 95.94 Mo 42 |
| 183.85 W 74 |
| 106 |

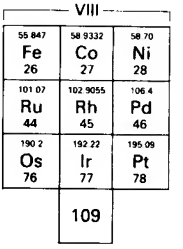
Crômio
Chrom
Chrom
Cromo
хром
כרום
鉻 クロム

**Naturally occurring isotopes:** 52, 53, 50, 54
**Density:** 7.20 g/cm$^3$ (20°C)
**Melting point:** 1857 ± 20°C **Boiling point:** 2672°C
**Latent heat of fusion:** 265.7 J/g
**Specific heat:** 0.449 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 6.2 × 10$^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 0.939 w/cm/°C (25°C)
**Electrical resistivity:** 12.9 × 10$^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 6.766 eV
**Electron work function $\phi$:** 4.5 eV
**Oxidation potential:** $Cr \rightarrow Cr^{3+} + 3\epsilon = 0.744$ V
**Chemical valence:** 1, 2, 3, 4, 5, *6*
**Electrochemical equivalents:** 0.32333 g/amp-hr
**Ionic radius:** 0.52 Å ($Cr^{6+}$)
**Valence electron potential (−$\epsilon$V):** 170
**Principal quantum number:** 4
**Principal electron shells:** K L M N
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$
**Valence electrons:** $3d^5\ 4s^1$
**Crystal form:** Cubic, body centered
**Cross section $\sigma$:** 3.1 ± 0.2 barns
**Vapor pressure:** 9.90 × 10$^2$ Pa (at melting point)

# Co Cobalt

27

58.9332




**Cobalto**
**Cobalt**
**Kobalt**
**Cobalto**
**кобальт**
**קובלט**
鈷 コバルト

**Naturally occurring isotope:** 59
**Density:** 8.71 g/cm$^3$ (21°C)
**Melting point:** 1495°C **Boiling point:** 2870°C
**Latent heat of fusion:** 258.6 J/g
**Specific heat:** 4.21 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 13.80 × $10^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 1.00 w/cm/°C (25°C)
**Electrical resistivity:** 6.24 × $10^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 7.86 eV
**Electron work function $\phi$:** 5.0 eV
**Oxidation potential:** $Co \rightarrow Co^{2+} + 2\epsilon = 0.277$ V
**Chemical valence:** *2*, 3, 4
**Electrochemical equivalents:** 1.0994 g/amp-hr
**Ionic radius:** 0.745 Å ($Co^{3+}$)
**Valence electron potential ($-\varepsilon$V):** 38.7
**Principal quantum number:** 4
**Principal electron shells:** K L M N
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^7\ 4s^2$
**Valence electrons:** $3d^7\ 4s^2$
**Crystal form:** Hexagonal, close packed
**Cross section $\sigma$:** 37.5 ± 0.2 barns
**Vapor pressure:** 1.75 × $10^2$ Pa (at melting point)

# Cu Copper

29

63.546

IB

| 63.546 |
|---|
| Cu |
| 29 |
| 107.868 |
| Ag |
| 47 |
| 196.9665 |
| Au |
| 79 |

Cobre
Cuivre
Kupfer
Cobre
медь
נחושת
銅 铜

**Naturally occurring isotopes:** 63, 65
**Density:** 8.96 g/cm$^3$ (25°C)
**Melting point:** 1083.4 ± 0.2°C **Boiling point:** 2567°C
**Latent heat of fusion:** 205.6 J/g
**Specific heat:** 0.3845 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 16.6 × $10^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 4.01 w/cm/°C (25°C)
**Electrical resistivity:** 1.678 × $10^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 7.726 eV
**Electron work function $\phi$:** 4.65 eV
**Oxidation potentials:** $Cu \rightarrow Cu^+ + \epsilon = -0.521$ V
$Cu \rightarrow Cu^{2+} + 2\epsilon = -0.3419$ V
**Chemical valence:** 1, *2*
**Electrochemical equivalents:** 1.1855 g/amp-hr
**Ionic radius:** 0.73 Å ($Cu^{2+}$)
**Valence electron potential ($-\varepsilon V$):** 34
**Principal quantum number:** 4
**Principal electron shells:** K L M N
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$
**Valence electrons:** $3d^{10}\ 4s^1$
**Crystal form:** Cubic, face centered
**Cross section $\sigma$:** 3.8 ± 0.1 barns
**Vapor pressure:** 5.05 × $10^{-2}$ Pa (at melting point)

# Cm Curium

96

247.07038

Actinide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 232.03807 Th 90 | 231.0359 Pa 91 | 238.029 U 92 | 237.0482 Np 93 | 244.06423 Pu 94 | 243.0614 Am 95 | 247.07038 Cm 96 | 247.07032 Bk 97 | 251.07961 Cf 98 | 254.08805 Es 99 |
| 257.09515 Fm 100 | 258 Md 101 | 259 No 102 | 260 Lr 103 | | | | | | |

Cúrio
Curium
Curium
Curio
кюрий
קיוריום
鋦 キュリウム

**Naturally occurring isotopes:** None
**Density:** 13.51 g/cm$^3$ (25°C)
**Melting point:** 1340 ± 40°C **Boiling point:** 3110°C
**Ionization potential (1st):** 6.02 eV
**Oxidation potential:** $Cm \rightarrow Cm^{3+} + 3\epsilon = 2.07$ V
**Chemical valence:** *3,* 4
**Electrochemical equivalents:** 3.0727 g/amp-hr
**Ionic radius:** 0.970 Å ($Cm^{3+}$)
**Valence electron potential** ($-\epsilon$V): 44.5
**Principal quantum number:** 7
**Principal electron shells:** K L M N O P Q
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 5f^7\ 6s^2\ 6p^6\ 6d^1\ 7s^2$
**Valence electrons:** $5f^7\ 6d^1\ 7s^2$
**Crystal form:** Hexagonal
**Half life:** $1.6 \times 10^7$ years
**Cross section σ:** 180 barns

# Dy Dysprosium

66

162.50

Lanthanide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 140.12 Ce 58 | 140.9077 Pr 59 | 144.24 Nd 60 | 144.913 Pm 61 | 150.4 Sm 62 | 151.96 Eu 63 | 157.25 Gd 64 | 158.9254 Tb 65 | 162.50 Dy 66 | 164.9304 Ho 67 |
| 167.26 Er 68 | 168.9342 Tm 69 | 173.04 Yb 70 | 174.97 Lu 71 | | | | | | |

**Disprósio**
**Dysprosium**
**Dysprosium**
**Disprosio**
**диспрозий**
**דיספּרוזיום**
鏑 ジスプロシウム

**Naturally occurring isotopes:** 164, 162, 163, 161, 160, 158, 156
**Density:** 8.550 g/cm$^3$ (25°C)
**Melting point:** 1412°C **Boiling point:** 2562°C
**Latent heat of fusion:** 105.6 J/g
**Specific heat:** 173 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 8.6 $\times$ 10$^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 0.107 w/cm/°C (25°C)
**Electrical resistivity:** 90 $\times$ 10$^{-6}$ ohm-cm (25°C)
**Ionization potential (1st):** 5.928 eV
**Oxidation potential:** Dy $\rightarrow$ Dy$^{3+}$ + 3$\epsilon$ = 2.353 V
**Chemical valence:** 3
**Electrochemical equivalents:** 2.0210 g/amp-hr
**Ionic radius:** 0.912 Å (Dy$^{3+}$)
**Valence electron potential (−εV):** 47.4
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** 1s$^2$ 2s$^2$ 2p$^6$ 3s$^2$ 3p$^6$ 3d$^{10}$ 4s$^2$ 4p$^6$ 4d$^{10}$ 4f$^{10}$ 5s$^2$ 5p$^6$ 6s$^2$
**Valence electrons:** 4f$^{10}$ 6s$^2$
**Crystal form:** Hexagonal, close packed
**Cross section σ:** 930 ± 20 barns

# Es Einsteinium

99

254.08805

Einstênio
Einsteinium
Einsteinium
Einstenio
эйнштейний
איינשטיינים
אינשטיניום

Actinide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 232.03807 Th 90 | 231.0359 Pa 91 | 238.029 U 92 | 237.0482 Np 93 | 244.06423 Pu 94 | 243.0614 Am 95 | 247.07038 Cm 96 | 247.07032 Bk 97 | 251.07961 Cf 98 | 254.08805 Es 99 |
| 257.09515 Fm 100 | 258 Md 101 | 259 No 102 | 260 Lr 103 | | | | | | |

**Naturally occurring isotopes:** None
**Melting point:** 860 ± 30°C
**Ionization potential (1st):** 6.42 eV
**Oxidation potential:** $Es \rightarrow Es^{2+} + 2\epsilon = 2.3$ V
**Chemical valence:** *2,* 3
**Electrochemical equivalents:** 4.7400 g/amp-hr
**Ionic radius:** 0.925 Å ($Es^{3+}$)
**Principal quantum number:** 7
**Principal electron shells:** K L M N O P Q
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 5f^{11}\ 6s^2\ 6p^6\ 7s^2$
**Valence electrons:** $5f^{11}\ 7s^2$
**Crystal form:** Cubic, face centered
**Half life:** 276 days
**Cross section σ:** < 40 barns

# Er Erbium

68

167.26

Lanthanide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 140.12 Ce 58 | 140.9077 Pr 59 | 144.24 Nd 60 | 144.913 Pm 61 | 150.4 Sm 62 | 151.96 Eu 63 | 157.25 Gd 64 | 158.9254 Tb 65 | 162.50 Dy 66 | 164.9304 Ho 67 |
| 167.26 Er 68 | 168.9342 Tm 69 | 173.04 Yb 70 | 174.97 Lu 71 | | | | | | |

**Érbio**
**Erbium**
**Erbium**
**Erbio**
**эрбий**
**ארביום**
鉺 エルビウム

**Naturally occurring isotopes:** 166, 168, 167, 170, 164, 162
**Density:** 9.066 g/cm$^3$ (25°C)
**Melting point:** 1529°C **Boiling point:** 2863°C
**Latent heat of fusion:** 102.6 J/g
**Specific heat:** 0.168 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 9.2 × 10$^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 0.145 w/cm/°C (25°C)
**Electrical resistivity:** 107.0 × 10$^{-6}$ ohm-cm (25°C)
**Ionization potential (1st):** 6.10 eV
**Oxidation potential:** Er → Er$^{3+}$ + 3$\epsilon$ = 2.296 V
**Chemical valence:** 3
**Electrochemical equivalents:** 2.0802 g/amp-hr
**Ionic radius:** 0.881 Å (Er$^{3+}$)
**Valence electron potential (−εV):** 49.0
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** 1s$^2$ 2s$^2$ 2p$^6$ 3s$^2$ 3p$^6$ 3d$^{10}$ 4s$^2$ 4p$^6$ 4d$^{10}$ 4f$^{12}$ 5s$^2$ 5p$^6$ 6s$^2$
**Valence electrons:** 4f$^{12}$ 6s$^2$
**Crystal form:** Hexagonal, close packed
**Cross section σ:** 160 ± 30 barns

# Eu Europium

63

151.96

Lanthanide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 140.12 Ce 58 | 140.9077 Pr 59 | 144.24 Nd 60 | 144.913 Pm 61 | 150.4 Sm 62 | 151.96 Eu 63 | 157.25 Gd 64 | 158.9254 Tb 65 | 162.50 Dy 66 | 164.9304 Ho 67 |
| 167.26 Er 68 | 168.9342 Tm 69 | 173.04 Yb 70 | 174.97 Lu 71 | | | | | | |

Európio
Europium
Europium
Europio
европий
אירופיום
銪 ユーロピウム

**Naturally occurring isotopes:** 153, 151
**Density:** 5.243 g/cm$^3$ (25°C)
**Melting point:** 822°C **Boiling point:** 1597°C
**Latent heat of fusion:** 68.9 J/g
**Specific heat:** 0.182 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 26 × 10$^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 0.139 w/cm/°C (25°C)
**Electrical resistivity:** 81 × 10$^{-6}$ ohm-cm (25°C)
**Ionization potential (1st):** 5.666 eV
**Electron work function** $\phi$**:** 2.5 eV
**Oxidation potential:** Eu → Eu$^{3+}$ + 3$\epsilon$ = 2.407 V
**Chemical valence:** 2, *3*
**Electrochemical equivalents:** 1.8899 g/amp-hr
**Ionic radius:** 0.947 Å (Eu$^{3+}$)
**Valence electron potential (−**$\varepsilon$**V):** 45.6
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** 1s$^2$ 2s$^2$ 2p$^6$ 3s$^2$ 3p$^6$ 3d$^{10}$ 4s$^2$ 4p$^6$ 4d$^{10}$ 4f$^7$ 5s$^2$ 5p$^6$ 6s$^2$
**Valence electrons:** 4f$^7$ 6s$^2$
**Crystal form:** Cubic, body centered
**Cross section** $\sigma$**:** 4100 ± 100 barns
**Vapor pressure:** 1.44 × 10$^2$ Pa (at melting point)

# Fm Fermium

100

257.09515

Actinide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 232.03807 Th 90 | 231.0359 Pa 91 | 238.029 U 92 | 237.0482 Np 93 | 244.06423 Pu 94 | 243.0614 Am 95 | 247.07038 Cm 96 | 247.07032 Bk 97 | 251.07961 Cf 98 | 254.08805 Es 99 |
| 257.09515 Fm 100 | 258 Md 101 | 259 No 102 | 260 Lr 103 | | | | | | |

Fermio
Fermium
Fermium
Fermio
фермий
פרמיום
鐨 フェリミウム

**Naturally occurring isotopes:** None
**Ionization potential (1st):** 6.50 eV
**Oxidation potential:** $Fm \rightarrow Fm^{3+} + 3\epsilon = 2.0$ V
**Chemical valence:** 2, *3*
**Electrochemical equivalents:** 3.1974 g/amp-hr
**Principal quantum number:** 7
**Principal electron shells:** K L M N O P Q
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 5f^{12}\ 6s^2\ 6p^6\ 7s^2$
**Valence electrons:** $5f^{12}\ 7s^2$
**Half life:** 80 days

# Fluorine

9

18.998403

VIIA

| |
|---|
| 18.998403<br>F<br>9 |
| 35.453<br>Cl<br>17 |
| 79.904<br>Br<br>35 |
| 126.9045<br>I<br>53 |
| 209.987<br>At<br>85 |

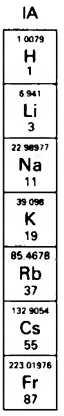
Flúor
Fluor
Fluor
Flúor
фтор
פלואור
氟 弗素

**Naturally occurring isotope:** 19
**Density:** $1.696 \times 10^{-3}$ g/cm$^3$ (0°C)
**Melting point:** −219.62°C **Boiling point:** −188.14°C
**Latent heat of fusion:** 26.89 J/g ($F_2$)
**Specific heat:** 0.824 J/g/°C ($F_2$) (25°C)
**Thermal conductivity:** 0.279 mw/cm/°C (27°C at 1 atm)
**Ionization potential (1st):** 17.422 eV
**Oxidation potential:** $F^- \rightarrow \frac{1}{2}F_2 + \epsilon = -2.87$ V
**Chemical valence:** −1
**Electrochemical equivalents:** 0.70883 g/amp-hr
**Ionic radius:** 1.33 Å ($F^-$)
**Valence electron potential (−εV):** −10.1
**Principal quantum number:** 2
**Principal electron shells:** K L
**Electronic configuration:** $1s^2\ 2s^2\ 2p^5$
**Valence electrons:** $2s^2\ 2p^5$
**Cross section σ:** 9.8 ± 0.7 mbarns
**Vapor pressure:** $4.90 \times 10^2$ Pa (at melting point)

# Fr Francium

87

223.01976




**Frâncio**
**Francium**
**Franzium**
**Francio**
**франций**
**פרנציום**
**钫 ワランシウム**

**Naturally occurring isotopes:** None (actinium decay product)
**Melting point:** 27°C (est) **Boiling point:** 677°C (est)
**Latent heat of fusion:** 9.39 J/g (est)
**Ionization potential (1st):** 3.83 eV
**Chemical valence:** 1
**Electrochemical equivalents:** 8.3209 g/amp-hr
**Ionic radius:** 1.80 Å ($Fr^+$)
**Valence electron potential (−εV):** 8.00
**Principal quantum number:** 7
**Principal electron shells:** K L M N O P Q
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 6s^2\ 6p^6\ 7s^1$
**Valence electrons:** ($7s^1$)
**Half life:** 22 minutes
**Crystal form:** Cubic, body centered

# Gd Gadolinium

64

157.25

Gadolínio
Gadolinium
Gadolinium
Gadolinio
гадолиний
גדוליניום
釓 ガドリニウム

Lanthanide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 140.12 Ce 58 | 140.9077 Pr 59 | 144.24 Nd 60 | 144.913 Pm 61 | 150.4 Sm 62 | 151.96 Eu 63 | 157.25 Gd 64 | 158.9254 Tb 65 | 162.50 Dy 66 | 164.9304 Ho 67 |
| 167.26 Er 68 | 168.9342 Tm 69 | 173.04 Yb 70 | 174.97 Lu 71 | | | | | | |

**Naturally occurring isotopes:** 158, 160, 156, 157, 155, 154, 152
**Density:** 7.900 g/cm$^3$ (25°C)
**Melting point:** 1313°C **Boiling point:** 3266°C
**Latent heat of fusion:** 98.51 J/g
**Specific heat:** 0.235 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 9.7 × 10$^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 0.105 w/cm/°C (25°C)
**Electrical resistivity:** 140.5 × 10$^{-6}$ ohm-cm (25°C)
**Ionization potential (1st):** 6.14 eV
**Electron work function $\phi$:** 3.1 eV
**Oxidation potential:** $Gd \rightarrow Gd^{3+} + 3\epsilon = 2.397$ V
**Chemical valence:** 3
**Electrochemical equivalents:** 1.9557 g/amp-hr
**Ionic radius:** 0.938 Å ($Gd^{3+}$)
**Valence electron potential ($-\varepsilon$V):** 46.1
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^7\ 5s^2\ 5p^6\ 5d^1\ 6s^2$
**Valence electrons:** $4f^7\ 5d^1\ 6s^2$
**Crystal form:** Hexagonal, close packed
**Cross section $\sigma$:** 46,000 ± 2000 barns
**Vapor pressure:** 2.44 × 10$^4$ Pa (at melting point)

# Ga Gallium

31

69.72

IIIA

| |
|---|
| 10.81 B 5 |
| 26.98154 Al 13 |
| 69.72 Ga 31 |
| 114.82 In 49 |
| 204.37 Tl 81 |

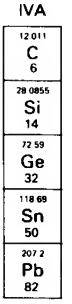
**Gálio**
**Gallium**
**Gallium**
**Galio**
**галлий**
**גליום**
鎵 ガリウム

**Naturally occurring isotopes:** 69, 71
**Density:** 5.906 g/cm$^3$ (25°C)
**Melting point:** 29.78°C **Boiling point:** 2403°C
**Latent heat of fusion:** 80.17 J/g
**Specific heat:** 0.371 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 18.1 $\times$ 10$^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 0.281 w/cm/°C (liquid) (30°C)
**Electrical resistivity:** 17.4 $\times$ 10$^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 5.999 eV
**Electron work function $\phi$:** 4.2 eV
**Oxidation potential:** Ga $\rightarrow$ Ga$^{3+}$ + 3$\epsilon$ = $-$0.529 V
**Chemical valence:** 2, *3*
**Electrochemical equivalents:** 0.8671 g/amp-hr
**Ionic radius:** 0.620 Å (Ga$^{3+}$)
**Valence electron potential ($-\varepsilon$V):** 69.7
**Principal quantum number:** 4
**Principal electron shells:** K L M N
**Electronic configuration:** 1s$^2$ 2s$^2$ 2p$^6$ 3s$^2$ 3p$^6$ 3d$^{10}$ 4s$^2$ 4p$^1$
**Valence electrons:** 4s$^2$ 4p$^1$
**Crystal form:** Orthorhombic, rhombic
**Cross section $\sigma$:** 3.1 $\pm$ 0.3 barns
**Vapor pressure:** 9.31 $\times$ 10$^{-36}$ Pa (at melting point)

# Ge Germanium

32

72.59




**Germânio**
**Germanium**
**Germanium**
**Germanio**
**германий**
**גרמניום**
**鍺 ゲルマニウム**

**Naturally occurring isotopes:** 74, 72, 70, 73, 76
**Density:** 5.323 g/cm$^3$ (25°C)
**Melting point:** 937.4°C **Boiling point:** 2830°C
**Latent heat of fusion:** 438.3 J/g
**Specific heat:** 0.3216 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 5.75 × $10^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 0.667 w/cm/°C (25°C)
**Electrical resistivity:** 47 ohm-cm (intrinsic resistivity) (22°C)
**Ionization potential (1st):** 7.899 eV
**Electron work function $\phi$:** 5.0 eV
**Oxidation potential:** $Ge + 2H_2O \rightarrow GeO_2 + 4H^+ + 4\epsilon = -0.15$ V
**Chemical valence:** −4, 2, *4*
**Electrochemical equivalents:** 0.6771 g/amp-hr
**Ionic radius:** 0.530 Å ($Ge^{4+}$)
**Valence electron potential (−$\varepsilon$V):** 109
**Principal quantum number:** 4
**Principal electron shells:** K L M N
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^2$
**Valence electrons:** $4s^2\ 4p^2$
**Crystal form:** Cubic, diamond
**Cross section $\sigma$:** 2.30 ± 0.26 barns
**Vapor pressure:** 7.46 × $10^{-5}$ Pa (at melting point)

# Au Gold

79

196.9665

IB

| 63.546 |
|---|
| Cu |
| 29 |
| 107.868 |
| Ag |
| 47 |
| 196.9665 |
| Au |
| 79 |

Ouro
Or
Gold
Oro
золото
זהב
金 金

**Naturally occurring isotope:** 197
**Density:** 19.32 g/cm$^3$ (20°C)
**Melting point:** 1064.43°C **Boiling point:** 3080°C
**Latent heat of fusion:** 62.81 J/g
**Specific heat:** 0.1290 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 14.2 $\times$ 10$^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 3.19 w/cm/°C (25°C)
**Electrical resistivity:** 2.44 $\times$ 10$^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 9.225 eV
**Electron work function $\phi$:** 5.1 eV
**Oxidation potentials:** $Au \rightarrow Au^+ + \epsilon = -1.691$ V
$Au \rightarrow Au^{3+} + 3\epsilon = -1.498$ V
**Chemical valence:** 1, *3*
**Electrochemical equivalents:** 2.4496 g/amp-hr
**Ionic radius:** 0.85 Å ($Au^{3+}$)
**Valence electron potential ($-\epsilon$V):** 51
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 6s^1$
**Valence electrons:** $5d^{10}\ 6s^1$
**Crystal form:** Cubic, face centered
**Cross section $\sigma$:** 98.8 $\pm$ 0.3 barns
**Vapor pressure:** 2.37 $\times$ 10$^{-4}$ Pa (at melting point)

# Hf Hafnium

72

178.49

IVB

| |
|---|
| 47.90<br>Ti<br>22 |
| 91.22<br>Zr<br>40 |
| 178.49<br>Hf<br>72 |
| 104 |

Háfnio
Hafnium
Hafnium
Hafnio
гафний
הפניום
鉿 ハフニウム

**Naturally occurring isotopes:** 180, 178, 177, 179, 176, 174
**Density:** 13.31 g/cm$^3$ (20°C)
**Melting point:** 2227 ± 20°C **Boiling point:** 4602°C
**Latent heat of fusion:** 122.0 J/g
**Specific heat:** 0.144 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 5.6 × $10^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 0.230 w/cm/°C (25°C)
**Electrical resistivity:** 35.1 × $10^{-6}$ ohm-cm (25°C)
**Ionization potential (1st):** 6.65 eV
**Electron work function** $\phi$**:** 3.9 eV
**Oxidation potential:** $Hf \rightarrow Hf^{4+} + 4\epsilon = 1.70$ V
**Chemical valence:** 4
**Electrochemical equivalents:** 1.6649 g/amp-hr
**Ionic radius:** 0.71 Å ($Hf^{4+}$)
**Valence electron potential (**$-\varepsilon$**V):** 81
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^2\ 6s^2$
**Valence electrons:** $5d^2\ 6s^2$
**Crystal form:** Hexagonal, close packed
**Cross section** $\sigma$**:** 103 ± 3 barns
**Vapor pressure:** 1.12 × $10^{-3}$ Pa (at melting point)

# He Helium

2

4.00260

O

| |
|---|
| 4.00260 He 2 |
| 20.179 Ne 10 |
| 39.948 Ar 18 |
| 83.80 Kr 36 |
| 131.30 Xe 54 |
| 222.01761 Rn 86 |

**Hélio**
**Hélium**
**Helium**
**Helio**
**гелий**
**הליום**
氦 ヘリウム

**Naturally occurring isotopes:** 4, 3
**Density:** 0.17847 × $10^{-3}$ g/cm$^3$ (0°C)
**Melting point:** −272.2°C (26 atm); I **Boiling point:** −268.934°C
**Latent heat of fusion:** 5.23 J/g
**Specific heat:** 5.1930 J/g/°C (25°C)
**Thermal conductivity:** 1.520 mw/cm/°C (25°C at 1 atm)
**Ionization potential (1st):** 24.58 eV
**Chemical valence:** 0
**Principal quantum number:** 1
**Principal electron shells:** K
**Electronic configuration:** $1s^2$
**Valence electrons:** ($1s^2$)
**Crystal form:** Hexagonal, close packed
**Cross section σ:** 0.007 barns

# Ho Holmium

67

164.9304

Lanthanide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 140.12 Ce 58 | 140.9077 Pr 59 | 144.24 Nd 60 | 144.913 Pm 61 | 150.4 Sm 62 | 151.96 Eu 63 | 157.25 Gd 64 | 158.9254 Tb 65 | 162.50 Dy 66 | 164.9304 Ho 67 |
| 167.26 Er 68 | 168.9342 Tm 69 | 173.04 Yb 70 | 174.97 Lu 71 | | | | | | |

Hólmio
Holmium
Holmium
Holmio
холмий
הולמיום
鈥 ホルミウム

**Naturally occurring isotope:** 165
**Density:** 8.795 g/cm$^3$ (25°C)
**Melting point:** 1474°C **Boiling point:** 2695°C
**Latent heat of fusion:** 104.1 J/g
**Specific heat:** 0.165 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 9.5 × $10^{-6}$ cm/cm/°C (400°C)
**Thermal conductivity:** 0.162 w/cm/°C (25°C)
**Electrical resistivity:** 87.0 × $10^{-6}$ ohm-cm (25°C)
**Ionization potential (1st):** 6.02 eV
**Oxidation potential:** Ho → $Ho^{3+}$ + 3$\epsilon$ = 2.319 V
**Chemical valence:** 3
**Electrochemical equivalents:** 2.0512 g/amp-hr
**Ionic radius:** 0.901 Å ($Ho^{3+}$)
**Valence electron potential (−$\epsilon$V):** 47.9
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{11}\ 5s^2\ 5p^6\ 6s^2$
**Valence electrons:** $4f^{11}\ 6s^2$
**Crystal form:** Hexagonal, close packed
**Cross section $\sigma$:** 65 ± 2 barns

# H Hydrogen

1

1.0079

IA

| |
|---|
| 1.0079 H 1 |
| 6.941 Li 3 |
| 22.98977 Na 11 |
| 39.098 K 19 |
| 85.4678 Rb 37 |
| 132.9054 Cs 55 |
| 223.01976 Fr 87 |

**Hidrogênio**
**Hydrogène**
**Wasserstoff**
**Hidrógeno**
**водород**
**מימן**
**水素 気**

**Naturally occurring isotopes:** 1.007825 (protium), 2.01410 (deuterium), 3.01605 (tritium)
**Density:** 0.08988 × $10^{-3}$ g/cm$^3$ (0°C)
**Melting point:** −259.14°C **Boiling point:** −252.87°C
**Latent heat of fusion:** 116.3 J/g ($H_2$)
**Specific heat:** 14.30 J/g/°C ($H_2$) (25°C)
**Thermal conductivity:** 1.815 mw/cm/°C (27°C at 1 atm)
**Ionization potential (1st):** 13.59765 eV
**Oxidation potentials:** $H_2 \rightarrow 2H^+ + \epsilon = 0.00000$ V
$H^- \rightarrow \frac{1}{2}H_2 + \epsilon = 2.25$ V
**Chemical valence:** 1
**Electrochemical equivalents:** 0.037605 g/amp-hr
**Ionic radius:** 0.012 Å ($H^+$)
**Valence electron potential (−εV):** 1200
**Principal quantum number:** 1
**Principal electron shells:** K
**Electronic configuration:** $1s^1$
**Valence electrons:** $1s^1$
**Crystal form:** Hexagonal, close packed
**Cross section σ:** 0.33 barns

# In Indium

49

114.82

IIIA

| |
|---|
| 10.81 B 5 |
| 26.98154 Al 13 |
| 69.72 Ga 31 |
| 114.82 In 49 |
| 204.37 Tl 81 |

Índio
Indium
Indium
Indio
индий
אינדיום
銦 インジウム

**Naturally occurring isotopes:** 115, 113
**Density:** 7.28 g/cm$^3$ (20°C)
**Melting point:** 156.61°C **Boiling point:** 2080°C
**Latent heat of fusion:** 28.44 J/g
**Specific heat:** 0.233 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 24.8 $\times$ 10$^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 0.818 w/cm/°C (25°C)
**Electrical resistivity:** 8.37 $\times$ 10$^{-6}$ ohm-cm (0°C)
**Ionization potential (1st):** 5.786 eV
**Electron work function $\phi$:** 4.12 eV
**Oxidation potential:** $In \rightarrow In^{3+} + 3\epsilon = 0.343$ V
**Chemical valence:** 1, 2, *3*
**Electrochemical equivalents:** 1.4280 g/amp-hr
**Ionic radius:** 0.800 Å ($In^{3+}$)
**Valence electron potential ($-\varepsilon$V):** 54.0
**Principal quantum number:** 5
**Principal electron shells:** K L M N O
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 5s^2\ 5p^1$
**Valence electrons:** $5s^2\ 5p^1$
**Crystal form:** Tetragonal
**Cross section $\sigma$:** 194 $\pm$ 2 barns
**Vapor pressure:** 1.42 $\times$ 10$^{17}$ Pa (at melting point)

# Iodine

53

126.9045

VIIA

| |
|---|
| 18.998403 F 9 |
| 35.453 Cl 17 |
| 79.904 Br 35 |
| 126.9045 I 53 |
| 209.987 At 85 |

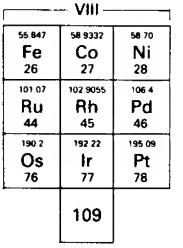
Iôdo
Iode
Iod
Yodo
иод
יוד
碘 沃素

**Naturally occurring isotope:** 127
**Density:** 4.93 g/cm$^3$ (20°C)
**Melting point:** 113.5°C **Boiling point:** 184.35°C
**Latent heat of fusion:** 124.4 J/g ($I_2$)
**Specific heat:** 0.21448 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 93 × $10^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 4.49 mw/cm/°C (27°C)
**Electrical resistivity:** 1.3 × $10^9$ ohm-cm (20°C)
**Ionization potential (1st):** 10.451 eV
**Oxidation potential:** $I^- \rightarrow \frac{1}{2}I_2 + \epsilon = -0.5355$ V
**Chemical valence:** *−1*, 3, 5, 7
**Electrochemical equivalents:** 4.7348 g/amp-hr
**Ionic radius:** 2.20 Å ($I^-$)
**Valence electron potential (−εV):** −6.55
**Principal quantum number:** 5
**Principal electron shells:** K L M N O
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 5s^2\ 5p^5$
**Valence electrons:** $5s^2\ 5p^5$
**Crystal form:** Orthorhombic
**Cross section σ:** 6.2 ± 0.2 barns

# Ir Iridium

77

192.22



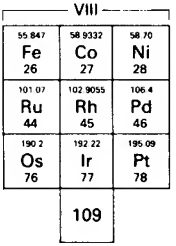

Irídio
Iridium
Iridium
Iridio
иридий
אירידיום
銥 イリジウム

**Naturally occurring isotopes:** 193, 191
**Density:** 22.42 g/cm$^3$ (17°C)
**Melting point:** 2410°C **Boiling point:** 4130°C
**Latent heat of fusion:** 137.2 J/g
**Specific heat:** 0.131 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** $6.6 \times 10^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 1.47 w/cm/°C (25°C)
**Electrical resistivity:** $4.71 \times 10^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 9.1 eV
**Electron work function $\phi$:** 5.27 eV
**Oxidation potential:** $Ir + 6Cl^- \rightarrow IrCl_6^{3-} + 3\epsilon = -0.77$ V
**Chemical valence:** 2, 3, *4*, 6
**Electrochemical equivalents:** 1.793 g/amp-hr
**Ionic radius:** 0.625 Å ($Ir^{4+}$)
**Valence electron potential ($-\varepsilon$V):** 92.2
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^7\ 6s^2$
**Valence electrons:** $5d^7\ 6s^2$
**Crystal form:** Cubic, face centered
**Cross section $\sigma$:** $425 \pm 15$ barns
**Vapor pressure:** 1.47 Pa (at melting point)

# Fe Iron

26

55.847




**Ferro**
**Fer**
**Eisen**
**Hierro**
**железо**
**ברזל**
**鉄 鉄**

**Naturally occurring isotopes:** 56, 54, 57, 58
**Density:** 7.874 g/cm$^3$ (20°C)
**Melting point:** 1535°C **Boiling point:** 2750°C
**Latent heat of fusion:** 275.1 J/g
**Specific heat:** 0.450 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 11.76 $\times$ $10^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 0.804 w/cm/°C (25°C)
**Electrical resistivity:** 9.71 $\times$ $10^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 7.870 eV
**Electron work function $\phi$:** 4.70 eV
**Oxidation potential:** $Fe \rightarrow Fe^{2+} + 2\epsilon = 0.4402$ V
**Chemical valence:** 2, *3,* 4, 6
**Electrochemical equivalents:** 0.69455 g/amp-hr
**Ionic radius:** 0.645 Å ($Fe^{3+}$)
**Valence electron potential ($-\varepsilon$V):** 67.0
**Principal quantum number:** 4
**Principal electron shells:** K L M N
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^2$
**Valence electrons:** $3d^6\ 4s^2$
**Crystal form:** Cubic, body centered
**Cross section $\sigma$:** 2.56 $\pm$ 0.05 barns
**Vapor pressure:** 7.05 Pa (at melting point)

# Kr Krypton

36

83.80

O

| |
|---|
| 4.00260 He 2 |
| 20.179 Ne 10 |
| 39.948 Ar 18 |
| 83.80 Kr 36 |
| 131.30 Xe 54 |
| 222.01761 Rn 86 |

Criptônio
Krypton
Krypton
Criptón
криптон
קריפטון
氪 クリプトン

**Naturally occurring isotopes:** 84, 86, 82, 83, 80, 78
**Density:** $3.733 \times 10^{-3}$ g/cm$^3$ (20°C)
**Melting point:** −156.6°C **Boiling point:** −152.30 ± 0.10°C
**Latent heat of fusion:** 19.54 J/g
**Specific heat:** 0.24804 J/g/°C (25°C)
**Thermal conductivity:** 0.0949 mw/cm/°C (27°C)
**Ionization potential (1st):** 13.999 eV
**Chemical valence:** 0
**Principal quantum number:** 4
**Principal electron shells:** K L M N
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6$
**Valence electrons:** ($4s^2\ 4p^6$)
**Crystal form:** Cubic, face centered (solid)
**Cross section σ:** 24.5 ± 1.0 barns

# La Lanthanum

57

138.9055

IIIB

| 44.95592 |
|---|
| Sc |
| 21 |
| 88.9059 |
| Y |
| 39 |
| 138.9055 |
| La |
| 57 |
| 227.02777 |
| Ac |
| 89 |

Lantânio
Lanthane
Lanthan
Lantano
лантан
לנתן
鑭 ランタン

**Naturally occurring isotopes:** 139, 138
**Density:** 6.145 g/cm$^3$ (25°C)
**Melting point:** 921°C **Boiling point:** 3457°C
**Latent heat of fusion:** 81.4 J/g
**Specific heat:** 0.195 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 5.2 × 10$^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 0.134 w/cm/°C (25°C)
**Electrical resistivity:** 56 × 10$^{-6}$ ohm-cm (25°C)
**Ionization potential (1st):** 5.577 eV
**Electron work function $\phi$:** 3.5 eV
**Oxidation potential:** La → La$^{3+}$ + 3$\epsilon$ = 2.522 V
**Chemical valence:** 3
**Electrochemical equivalents:** 1.7275 g/amp-hr
**Ionic radius:** 1.061 Å (La$^{3+}$)
**Valence electron potential (−$\varepsilon$V):** 40.71
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** 1s$^2$ 2s$^2$ 2p$^6$ 3s$^2$ 3p$^6$ 3d$^{10}$ 4s$^2$ 4p$^6$ 4d$^{10}$ 5s$^2$ 5p$^6$ 5d$^1$ 6s$^2$
**Valence electrons:** 5d$^1$ 6s$^2$
**Crystal form:** Hexagonal, close packed
**Cross section $\sigma$:** 8.9 ± 0.2 barns
**Vapor pressure:** 1.33 × 10$^{-7}$ Pa (at melting point)

# Lr Lawrencium

103

260

Laurêncio
Lawrencium
Lawrenzium
Lawrencio
лавренций

テーレンチウム

Actinide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 232.03807 Th 90 | 231.0358 Pa 91 | 238.029 U 92 | 237.0482 Np 93 | 244.06423 Pu 94 | 243.0614 Am 95 | 247.07036 Cm 96 | 247.07032 Bk 97 | 251.07961 Cf 98 | 254.08805 Es 99 |
| 257.09515 Fm 100 | 258 Md 101 | 259 No 102 | 260 Lr 103 | | | | | | |

**Naturally occurring isotopes:** None
**Oxidation potential:** $Lr \rightarrow Lr^{3+} + 3\epsilon = 2.0\ V$
**Chemical valence:** 3
**Electrochemical equivalents:** 3.23 g/amp-hr
**Principal quantum number:** 7
**Principal electron shells:** K L M N O P Q
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 5f^{14}\ 6s^2\ 6p^6\ 6d^1\ 7s^2$
**Valence electrons:** $5f^{14}\ 6d^1\ 7s^2$
**Half life:** 3 minutes

# Pb Lead

82

207.2

IVA

| |
|---|
| 12.011<br>C<br>6 |
| 28.0855<br>Si<br>14 |
| 72.59<br>Ge<br>32 |
| 118.69<br>Sn<br>50 |
| 207.2<br>Pb<br>82 |

**Chumbo**
**Plomb**
**Blei**
**Plomo**
**свинец**
**עופרת**
**鉛 鉛**

**Naturally occurring isotopes:** 208, 206, 207, 204
**Density:** 11.342 g/cm$^3$ (20°C)
**Melting point:** 327.502°C **Boiling point:** 1740°C
**Latent heat of fusion:** 23.06 J/g
**Specific heat:** 0.128 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 28.3 $\times$ 10$^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 0.353 w/cm/°C (25°C)
**Electrical resistivity:** 20.65 $\times$ 10$^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 7.416 eV
**Electron work function $\phi$:** 4.25 eV
**Oxidation potential:** Pb $\rightarrow$ Pb$^{2+}$ + 2$\epsilon$ = 0.126 V
**Chemical valence:** *2,* 4
**Electrochemical equivalents:** 3.865 g/amp-hr (Pb$^{2+}$)
**Ionic radius:** 1.19 Å (Pb$^{2+}$)
**Valence electron potential ($-\varepsilon$V):** 24.2
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** 1s$^2$ 2s$^2$ 2p$^6$ 3s$^2$ 3p$^6$ 3d$^{10}$ 4s$^2$ 4p$^6$ 4d$^{10}$ 4f$^{14}$ 5s$^2$ 5p$^6$ 5d$^{10}$ 6s$^2$ 6p$^2$
**Valence electrons:** 6s$^2$ 6p$^2$
**Crystal form:** Cubic, face centered
**Cross section $\sigma$:** 180 $\pm$ 10 mbarns
**Vapor pressure:** 4.21 $\times$ 10$^{-7}$ Pa (at melting point)

# Li Lithium

3

6.941

IA

| |
|---|
| 1.0079 H 1 |
| 6.941 Li 3 |
| 22.98977 Na 11 |
| 39.098 K 19 |
| 85.4678 Rb 37 |
| 132.9054 Cs 55 |
| 223.01976 Fr 87 |

Litio
Lithium
Lithium
Litio
литий
ליתיום
鋰 リチウム

**Naturally occurring isotopes:** 7, 6
**Density:** 0.534 g/cm$^3$ (20°C)
**Melting point:** 180.54°C **Boiling point:** 1342°C
**Latent heat of fusion:** 430.1 J/g
**Specific heat:** 3.57 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** $60 \times 10^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 0.848 w/cm/°C (25°C)
**Electrical resistivity:** $8.55 \times 10^{-6}$ ohm-cm (0°C)
**Ionization potential (1st):** 5.392 eV
**Electron work function $\phi$:** 2.9 eV
**Oxidation potential:** $Li \rightarrow Li^+ + \epsilon = 3.045$ V
**Chemical valence:** 1
**Electrochemical equivalents:** 0.2590 g/amp-hr
**Ionic radius:** 0.76 Å ($Li^+$)
**Valence electron potential ($-\varepsilon V$):** 19
**Principal quantum number:** 2
**Principal electron shells:** K L
**Electronic configuration:** $1s^2\ 2s^1$
**Valence electrons:** $2s^1$
**Crystal form:** Cubic, body centered
**Cross section $\sigma$:** 71 barns
**Vapor pressure:** $1.63 \times 10^{-8}$ Pa (at melting point)

# Lu Lutetium

71

174.97

Lanthanide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 140.12 Ce 58 | 140.9077 Pr 59 | 144.24 Nd 60 | 144.913 Pm 61 | 150.4 Sm 62 | 151.96 Eu 63 | 157.25 Gd 64 | 158.9254 Tb 65 | 162.50 Dy 66 | 164.9304 Ho 67 |
| 167.26 Er 68 | 168.9342 Tm 69 | 173.04 Yb 70 | 174.97 Lu 71 | | | | | | |

**Lutécio**
**Lutetium**
**Lutetium**
**Lutecio**
**лютеций**
**לוטציום**
**鑥 ルテチウム**

**Naturally occurring isotopes:** 175, 176
**Density:** 9.840 g/cm$^3$ (25°C)
**Melting point:** 1663°C **Boiling point:** 3395°C
**Latent heat of fusion:** 110.1 J/g
**Specific heat:** 0.154 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 12.5 $\times$ 10$^{-6}$ cm/cm/°C (400°C)
**Thermal conductivity:** 0.164 w/cm/°C (25°C)
**Electrical resistivity:** 79.0 $\times$ 10$^{-6}$ ohm-cm (25°C)
**Ionization potential (1st):** 5.4259 eV
**Electron work function $\phi$:** 3.3 eV
**Oxidation potential:** Lu $\rightarrow$ Lu$^{3+}$ + 3$\epsilon$ = 2.255 V
**Chemical valence:** 3
**Electrochemical equivalents:** 2.1760 g/amp-hr
**Ionic radius:** 0.848 Å (Lu$^{3+}$)
**Valence electron potential ($-\varepsilon$V):** 50.9
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** 1s$^2$ 2s$^2$ 2p$^6$ 3s$^2$ 3p$^6$ 3d$^{10}$ 4s$^2$ 4p$^6$ 4d$^{10}$ 4f$^{14}$ 5s$^2$ 5p$^6$ 5d$^1$ 6s$^2$
**Valence electrons:** 5d$^1$ 6s$^2$
**Crystal form:** Hexagonal, close packed
**Cross section $\sigma$:** 75 $\pm$ 2 barns
**Vapor pressure:** 2.46 $\times$ 10$^3$ Pa (at melting point)

# Mg Magnesium

12

24.305

IIA

| |
|---|
| 9.01218<br>Be<br>4 |
| 24.305<br>Mg<br>12 |
| 40.08<br>Ca<br>20 |
| 87.62<br>Sr<br>38 |
| 137.34<br>Ba<br>56 |
| 226.02544<br>Ra<br>88 |

**Magnésio**
**Magnésium**
**Magnesium**
**Magnesio**
**магний**
**מגנזיום**
**鎂 マグネシウム**

**Naturally occurring isotopes:** 24, 26, 25
**Density:** 1.738 g/cm$^3$ (20°C)
**Melting point:** 648.8 ± 0.5°C **Boiling point:** 1090°C
**Latent heat of fusion:** 368.6 J/g
**Specific heat:** 102 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 27.1 × $10^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 1.56 w/cm/°C (20°C)
**Electrical resistivity:** 4.45 × $10^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 7.646 eV
**Electron work function $\phi$:** 3.66 eV
**Oxidation potential:** $Mg \rightarrow Mg^{2+} + 2\epsilon = 2.363$ V
**Chemical valence:** 2
**Electrochemical equivalents:** 0.45341 g/amp-hr
**Ionic radius:** 0.72 Å ($Mg^{2+}$)
**Valence electron potential ($-\varepsilon$V):** 40
**Principal quantum number:** 3
**Principal electron shells:** K L M
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2$
**Valence electrons:** $3s^2$
**Crystal form:** Hexagonal, close packed
**Cross section $\sigma$:** 64 ± 2 mbarns
**Vapor pressure:** 3.61 × $10^2$ (at melting point)

# Mn Manganese

25

54.9380

VIIB

| 54.9380 |
|---|
| Mn |
| 25 |
| 96.906 |
| Tc |
| 43 |
| 186.2 |
| Re |
| 75 |
| 107 |

Manganês
Manganese
Mangan
Manganeso
марганец
מנגן
錳 ヌンガン

**Naturally occurring isotope:** 55
**Density:** 7.44 g/cm$^3$ (20°C)
**Melting point:** 1244 ± 3°C **Boiling point:** 1962°C
**Latent heat of fusion:** 266.7 J/g
**Specific heat:** 0.479 J/g/°C (20°C)
**Coefficient of lineal thermal expansion:** 22 × 10$^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 78.1 mw/cm/°C (25°C)
**Electrical resistivity:** 185 × 10$^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 7.435 eV
**Electron work function** $\phi$**:** 4.1 eV
**Oxidation potential:** $Mn \rightarrow Mn^{2+} + 2\epsilon = 1.18$ V
**Chemical valence:** −2, −1, 0, 1, 2, 3, 4, 5, 6, 7
**Electrochemical equivalents:** 0.29282 g/amp-hr
**Ionic radius:** 0.46 Å ($Mn^{7+}$)
**Valence electron potential (**$-\epsilon$**V):** 220
**Principal quantum number:** 4
**Principal electron shells:** K L M N
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^2$
**Valence electrons:** $3d^5\ 4s^2$
**Crystal form:** Cubic, face centered
**Cross section** $\sigma$**:** 13.3 ± 0.1 barns
**Vapor pressure:** 1.21 × 10$^2$ Pa (at melting point)

# Md Mendelevium

101

258

Mendelévio
Mendelevium
Mendelevium
Mendelevio
менделевий
מנדלביום
鍆 メンデルビウム

Actinide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 232.03807 Th 90 | 231.0359 Pa 91 | 238.029 U 92 | 237.0482 Np 93 | 244.06423 Pu 94 | 243.0614 Am 95 | 247.07038 Cm 96 | 247.07032 Bk 97 | 251.07961 Cf 98 | 254.08805 Es 99 |
| 257.09515 Fm 100 | 258 Md 101 | 259 No 102 | 260 Lr 103 | | | | | | |

**Naturally occurring isotopes:** None
**Ionization potential (1st):** 6.58 eV
**Oxidation potential:** $Md \rightarrow Md^{3+} + 3\epsilon = 1.6$ V
**Chemical valence:** 1, 2, *3*
**Electrochemical equivalents:** 3.21 g/amp-hr
**Principal quantum number:** 7
**Principal electron shells:** K L M N O P Q
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 5f^{13}\ 6s^2\ 6p^6\ 7s^2$
**Valence electrons:** $5f^{13}\ 7s^2$
**Half life:** 55 days

# Hg Mercury

80

200.59

IIB

| |
|---|
| 65.38 Zn 30 |
| 112.41 Cd 48 |
| 200.59 Hg 80 |

Mercúrio
Mercure
Quecksilber
Mercurio
ртуть
כספית
汞 水銀

**Naturally occurring isotopes:** 202, 200, 199, 201, 198, 204, 196
**Density:** 13.534 g/cm$^3$ (25°C)
**Melting point:** −38.87°C **Boiling point:** 356.58°C
**Latent heat of fusion:** 11.46 J/g
**Specific heat:** 0.1395 J/g/°C (liquid) (25°C)
**Thermal conductivity:** 0.0830 w/cm/°C (25°C)
**Electrical resistivity:** 95.78 × $10^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 10.437 eV
**Electron work function** $\phi$**:** 4.49 eV
**Oxidation potential:** $Hg \rightarrow Hg^{2+} + 2\epsilon = -0.788$ V
**Chemical valence:** 1, *2*
**Electrochemical equivalents:** 3.7420 g/amp-hr
**Ionic radius:** 1.02 Å ($Hg^{2+}$)
**Valence electron potential (**$-\varepsilon V$**):** 28.2
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 6s^2$
**Valence electrons:** $6s^2$
**Crystal form:** Rhombohedral
**Cross section** $\sigma$**:** 375 ± 5 barns
**Vapor pressure:** 2.00 × $10^{-4}$ Pa (at melting point)

# Mo Molybdenum

42

95.94

VIB

| |
|---|
| 51.996<br>Cr<br>24 |
| 95.94<br>Mo<br>42 |
| 183.85<br>W<br>74 |
| 106 |

Molibdênio
Molybdène
Molybdän
Molibdeno
молибден
מוליבדן
鉬 モリブデン

**Naturally occurring isotopes:** 98, 96, 95, 92, 100, 97, 94
**Density:** 10.22 g/cm$^3$ (20°C)
**Melting point:** 2617°C **Boiling point:** 4612°C
**Latent heat of fusion:** 288.0 J/g
**Specific heat:** 0.251 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 6.6 × 10$^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 1.38 w/cm/°C (25°C)
**Electrical resistivity:** 5.2 × 10$^{-6}$ ohm-cm (0°C)
**Ionization potential (1st):** 7.099 eV
**Electron work function $\phi$:** 4.6 eV
**Oxidation potential:** Mo → Mo$^{3+}$ + 3$\epsilon$ = 0.2 V
**Chemical valence:** 2, 3, *4,* 5, 6
**Electrochemical equivalents:** 0.8949 g/amp-hr
**Ionic radius:** 0.650 Å (Mo$^{4+}$)
**Valence electron potential (−eV):** 88.6
**Principal quantum number:** 5
**Principal electron shells:** K L M N O
**Electronic configuration:** 1s$^2$ 2s$^2$ 2p$^6$ 3s$^2$ 3p$^6$ 3d$^{10}$ 4s$^2$ 4p$^6$ 4d$^5$ 5s$^1$
**Valence electrons:** 4d$^5$ 5s$^1$
**Crystal form:** Cubic, body centered
**Cross section $\sigma$:** 2.65 ± 0.05 barns
**Vapor pressure:** 3.47 Pa (at melting point)

# Nd Neodymium

60

144.24

Neodímio
Neodymium
Neodym
Neodimio
неодимий
ניאודימיום
钕 ネオジム

Lanthanide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 140.12 Ce 58 | 140.9077 Pr 59 | 144.24 Nd 60 | 144.913 Pm 61 | 150.4 Sm 62 | 151.96 Eu 63 | 157.25 Gd 64 | 158.9254 Tb 65 | 162.50 Dy 66 | 164.9304 Ho 67 |
| 167.26 Er 68 | 168.9342 Tm 69 | 173.04 Yb 70 | 174.97 Lu 71 | | | | | | |

**Naturally occurring isotopes:** 142, 144, 146, 143, 145, 148, 150
**Density:** 7.007 g/cm$^3$ (25°C)
**Melting point:** 1021°C **Boiling point:** 3068°C
**Latent heat of fusion:** 75.47 J/g
**Specific heat:** 0.190 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 8.6 × 10$^6$ cm/cm/°C (25°C)
**Thermal conductivity:** 0.165 w/cm/°C (25°C)
**Electrical resistivity:** 64.0 × 10$^{-6}$ ohm-cm (25°C)
**Ionization potential (1st):** 5.49 eV
**Electron work function** $\phi$**:** 3.2 eV
**Oxidation potential:** $Nd \rightarrow Nd^{3+} + 3\epsilon = 2.431$ V
**Chemical valence:** 2, *3*
**Electrochemical equivalents:** 1.7939 g/amp-hr
**Ionic radius:** 0.995 Å ($Nd^{3+}$)
**Valence electron potential (**$-\varepsilon$**V):** 43.4
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^4\ 5s^2\ 5p^6\ 6s^2$
**Valence electrons:** $4f^4\ 6s^2$
**Crystal form:** Hexagonal, close packed
**Cross section** $\sigma$**:** 49 ± 2 barns
**Vapor pressure:** 6.03 × 10$^{-3}$ Pa (at melting point)

# Ne Neon

10

20.179

O

| 4.00260 |
|---|
| He |
| 2 |
| 20.179 |
| Ne |
| 10 |
| 39.948 |
| Ar |
| 18 |
| 83.80 |
| Kr |
| 36 |
| 131.30 |
| Xe |
| 54 |
| 222.01761 |
| Rn |
| 86 |

Neônio
Neon
Neon
Neón
НЕОН
ניאון
氖 ネオン

**Naturally occurring isotopes:** 20, 22, 21
**Density:** 0.8999 × $10^{-3}$ g/cm$^3$ (20°C)
**Melting point:** −248.67°C **Boiling point:** −246.048°C
**Latent heat of fusion:** 16.6 J/g
**Specific heat:** 1.0301 J/g/°C (25°C)
**Thermal conductivity:** 0.493 mw/cm/°C (27°C)
**Ionization potential (1st):** 21.564 eV
**Chemical valence:** 0
**Principal quantum number:** 2
**Principal electron shells:** K L
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6$
**Valence electrons:** ($2s^2\ 2p^6$)
**Crystal form:** Cubic, face centered
**Cross section σ:** 38 ± 10 mbarns

# Np Neptunium

93

237.0482

Neptúnio
Neptunium
Neptunium
Neptunio
нептуний
נפטוניום
錼 ネプツニウム

Actinide Series

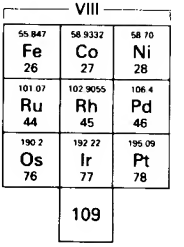
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 232.03807 Th 90 | 231.0359 Pa 91 | 238.029 U 92 | 237.0482 Np 93 | 244.06423 Pu 94 | 243.0614 Am 95 | 247.07038 Cm 96 | 247.07032 Bk 97 | 251.07961 Cf 98 | 254.08805 Es 99 |
| 257.09515 Fm 100 | 258 Md 101 | 259 No 102 | 260 Lr 103 | | | | | | |

**Naturally occurring isotopes:** None
**Density:** 20.45 g/cm$^3$ (25°C)
**Melting point:** 640 ± 1°C **Boiling point:** 3902°C
**Latent heat of fusion:** 46 J/g
**Thermal conductivity:** 63 mw/cm/°C (27°C)
**Electrical resistivity:** 119 × $10^{-6}$ ohm-cm (100°C)
**Ionization potential (1st):** 6.19 eV
**Oxidation potential:** Np → $Np^{3+}$ + 3ϵ = 1.856 V
**Chemical valence:** 3, 4, *5*, 6, 7
**Electrochemical equivalents:** 1.7689 g/amp-hr
**Ionic radius:** 0.75 Å ($Np^{5+}$)
**Valence electron potential (−εV):** 96
**Principal quantum number:** 7
**Principal electron shells:** K L M N O P Q
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 5f^4\ 6s^2\ 6p^6\ 6d^1\ 7s^2$
**Valence electrons:** $5f^4\ 6d^1\ 7s^2$
**Crystal form:** Orthorhombic
**Half life:** 2.14 × $10^4$ years
**Cross section σ:** 170 ± 5 barns

# Ni Nickel

28

58.70




Niquel
Nickel
Nickel
Niquel
никель
ניקל
鎳 ニッケル

**Naturally occurring isotopes:** 58, 60, 62, 61, 64
**Density:** 8.902 g/cm$^3$ (25°C)
**Melting point:** 1453°C **Boiling point:** 2732°C
**Latent heat of fusion:** 300.3 J/g
**Specific heat:** 0.444 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 13.3 × $10^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 0.909 w/cm/°C (25°C)
**Electrical resistivity:** 6.84 × $10^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 7.635 eV
**Electron work function $\phi$:** 5.15 eV
**Oxidation potential:** $Ni \rightarrow Ni^{2+} + 2\epsilon = 0.250$ V
**Chemical valence:** 0, 1, *2,* 3
**Electrochemical equivalents:** 1.095 g/amp-hr
**Ionic radius:** 0.69 Å ($Ni^{2+}$)
**Valence electron potential ($-\varepsilon V$):** 42
**Principal quantum number:** 4
**Principal electron shells:** K L M N
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^8\ 4s^2$
**Valence electrons:** $3d^8\ 4s^2$
**Crystal form:** Cubic, face centered
**Cross section $\sigma$:** 4.54 ± 0.10 barns
**Vapor pressure:** 2.37 × $10^2$ Pa (at melting point)

# Nb Niobium

41

92.9064

VB

| |
|---|
| 50.9415<br>V<br>23 |
| 92.9064<br>Nb<br>41 |
| 180.9479<br>Ta<br>73 |
| 105 |

Nióbio
Niobium
Niob
Niobio
ниобий
ניוביום
鈮 ニオブ

**Naturally occurring isotope:** 93
**Density:** 8.57 g/cm$^3$ (20°C)
**Melting point:** 2468 ± 10°C **Boiling point:** 4742°C
**Latent heat of fusion:** 288.4 J/g
**Specific heat:** 0.265 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 7.31 × $10^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 0.537 w/cm/°C (25°C)
**Electrical resistivity:** 14.6 × $10^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 6.88 eV
**Electron work function $\phi$:** 4.3 eV
**Oxidation potential:** $Nb \rightarrow Nb^{3+} + 3\epsilon = 1.099$ V
**Chemical valence:** 2, 3, 4, *5*
**Electrochemical equivalents:** 0.69327 g/amp-hr
**Ionic radius:** 0.69 Å ($Nb^{5+}$)
**Valence electron potential ($-\varepsilon$V):** 104
**Principal quantum number:** 5
**Principal electron shells:** K L M N O
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^4\ 5s^1$
**Valence electrons:** $4d^4\ 5s^1$
**Crystal form:** Cubic, face centered
**Cross section $\sigma$:** 1.15 ± 0.05 barns
**Vapor pressure:** 7.55 × $10^{-2}$ Pa (at melting point)

# N Nitrogen

7

14.0067

VA

| |
|---|
| 14.0067<br>N<br>7 |
| 30.97376<br>P<br>15 |
| 74.9216<br>As<br>33 |
| 121.75<br>Sb<br>51 |
| 208.9804<br>Bi<br>83 |

**Nitrogênio**
**Azote**
**Stickstoff**
**Nitrógeno**
**азот**
**חנקן**
**氮 窒素**

**Naturally occurring isotopes:** 14, 15
**Density:** 1.165 × $10^{-3}$ g/cm$^3$ (20°C)
**Melting point:** −209.86°C **Boiling point:** −195.8°C
**Latent heat of fusion:** 51.41 J/g ($N_2$)
**Specific heat:** 1.040 J/g/°C ($N_2$) (25°C)
**Thermal conductivity:** 0.2598 mw/cm/°C (27°C at 1 atm)
**Ionization potential (1st):** 14.534 eV
**Oxidation potential:** $N_2 + 2H_2O \rightarrow H_2N_2O_2 + 2H^+ + 2\epsilon = -2.65$ V
**Chemical valence:** −3, 3, *5*
**Electrochemical equivalents:** 0.10452 g/amp-hr
**Ionic radius:** 0.13 Å ($N^{5+}$)
**Valence electron potential (−εV):** 550
**Principal quantum number:** 2
**Principal electron shells:** K L
**Electronic configuration:** $1s^2\ 2s^2\ 2p^3$
**Valence electrons:** $2s^2\ 2p^3$
**Crystal form:** Hexagonal, close packed
**Cross section σ:** 1.9 barns

# No Nobelium

102

259

Nobélio
Nobelium
Nobelium
Nobelio
нобелий
נובליום
ノーベリウム

Actinide Series

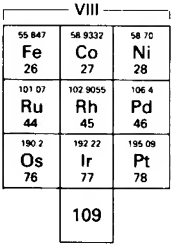
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 232.03807 Th 90 | 231.0359 Pa 91 | 238.029 U 92 | 237.0482 Np 93 | 244.06423 Pu 94 | 243.0614 Am 95 | 247.07038 Cm 96 | 247.07032 Bk 97 | 251.07961 Cf 98 | 254.08805 Es 99 |
| 257.09515 Fm 100 | 258 Md 101 | 259 No 102 | 260 Lr 103 | | | | | | |

**Naturally occurring isotopes:** None
**Ionization potential (1st):** 6.65 eV
**Oxidation potential:** $No \rightarrow No^{2+} + 2\epsilon = 2.5$ V
**Chemical valence:** *2,* 3
**Electrochemical equivalents:** 4.83 g/amp-hr
**Ionic radius:** 1.1 Å (est) ($No^{2+}$)
**Valence electron potential (−εV):** (26)
**Principal quantum number:** 7
**Principal electron shells:** K L M N O P Q
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 5f^{14}\ 6s^2\ 6p^6\ 7s^2$
**Valence electrons:** $5f^{14}\ 7s^2$
**Half life:** ~59 minutes

# Os Osmium

76

190.2




Osmio
Osmium
Osmium
Osmio
осмий
אוסמיום
鋨 オスミウム

**Naturally occurring isotopes:** 192, 190, 189, 188, 187, 186, 184
**Density:** 22.61 g/cm$^3$ (20°C)
**Melting point:** 3045 ± 30°C **Boiling point:** 5027 ± 100°C
**Latent heat of fusion:** 154.1 J/g
**Specific heat:** 0.13 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 6.3 × $10^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 0.876 w/cm/°C (25°C)
**Electrical resistivity:** 9.5 × $10^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 8.7 eV
**Electron work function $\phi$:** 4.83 eV
**Oxidation potential:** $Os + 4H_2O \rightarrow OsO_4 + 8H^+ + 8\epsilon = -0.85$ V
**Chemical valence:** 0, 1, 2, 3, *4*, 5, 6, 7, 8
**Electrochemical equivalents:** 1.774 g/amp-hr
**Ionic radius:** 0.630 Å ($Os^{4+}$)
**Valence electron potential ($-\varepsilon$V):** 91.4
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^6\ 6s^2$
**Valence electrons:** $5d^6\ 6s^2$
**Crystal form:** Hexagonal, close packed
**Cross section $\sigma$:** 15.3 ± 0.7 barns
**Vapor pressure:** 2.52 Pa (at melting point)

# O Oxygen

8

15.9994

VIA

| |
|---|
| 15.9994<br>O<br>8 |
| 32.06<br>S<br>16 |
| 78.96<br>Se<br>34 |
| 127.60<br>Te<br>52 |
| 208.98243<br>Po<br>84 |

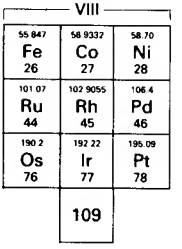
**Oxigênio**
**Oxygène**
**Sauerstoff**
**Oxigeno**
**кислород**
**חמצן**
**氧酸素**

**Naturally occurring isotopes:** 16, 18, 17
**Density:** $1.429 \times 10^{-3}$ g/cm$^3$ (0°C)
**Melting point:** −218.4°C **Boiling point:** −182.962°C
**Latent heat of fusion:** 26.17 J/g ($O_2$)
**Specific heat:** 0.9174 J/g/°C ($O_2$) (25°C)
**Thermal conductivity:** 0.2674 w/cm/°C (25°C at 1 atm)
**Ionization potential (1st):** 13.618 eV
**Oxidation potential:** $2H_2O$ (liquid) $\rightarrow O_2 + 4H^+ + 4\epsilon = -1.229$ V
**Chemical valence:** −2
**Electrochemical equivalents:** 0.29847 g/amp-hr
**Ionic radius:** 1.40 Å ($O^{2-}$)
**Valence electron potential (−εV):** −20.6
**Principal quantum number:** 2
**Principal electron shells:** K L
**Electronic configuration:** $1s^2\ 2s^2\ 2p^4$
**Valence electrons:** $2s^2\ 2p^4$
**Crystal form:** Cubic
**Cross section σ:** 0.27 mbarns

# Pd Palladium

46

106.4




**Paládio**
**Palladium**
**Palladium**
**Paladio**
**палладий**
**פלדיום**
**鈀 パラジウム**

---

**Naturally occurring isotopes:** 106, 108, 105, 110, 104, 102
**Density:** 12.023 g/cm$^3$ (20°C)
**Melting point:** 1554°C **Boiling point:** 3140°C
**Latent heat of fusion:** 157.4 J/g
**Specific heat:** 0.244 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 11.67 $\times$ 10$^{-6}$ cm/cm/°C (0°C)
**Thermal conductivity:** 0.718 w/cm/°C (25°C)
**Electrical resistivity:** 10.54 $\times$ 10$^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 8.34 eV
**Electron work function $\phi$:** 5.12 eV
**Oxidation potential:** $Pd \rightarrow Pd^{2+} + 2\epsilon = -0.987$ V
**Chemical valence:** *2*, 3, 4
**Electrochemical equivalents:** 1.985 g/amp-hr
**Ionic radius:** 0.86 Å ($Pd^{2+}$)
**Valence electron potential ($-\varepsilon$V):** 33
**Principal quantum number:** 5
**Principal electron shells:** K L M N O
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}$
**Valence electrons:** $4d^{10}$
**Crystal form:** Cubic, face centered
**Cross section $\sigma$:** 6.0 $\pm$ 1.0 barns
**Vapor pressure:** 1.33 Pa (at melting point)

# Phosphorus

15

30.97376

VA

| |
|---|
| 14.0067 N 7 |
| 30.97376 P 15 |
| 74.9216 As 33 |
| 121.75 Sb 51 |
| 208.9804 Bi 83 |

**Fósforo**
**Phosphore**
**Phosphor**
**Fósforo**
**фосфор**
**זרחן**
**磷 燐**

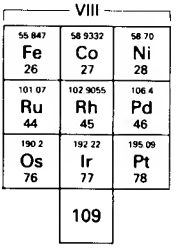
**Naturally occurring isotope:** 31
**Density:** 1.828 g/cm$^3$ (white), 2.34 g/cm$^3$ (red), 2.699 g/cm$^3$ (black) (all at 20°C)
**Melting point:** 44.1°C (white) **Boiling point:** 280.3°C (white)
**Latent heat of fusion:** 20.28 J/g (white)
**Specific heat:** 0.7697 J/g/°C (white) (25°C)
**Coefficient of lineal thermal expansion:** $125 \times 10^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 2.36 mw/cm/°C (white) (25°C)
**Electrical resistivity:** $10^{11}$ ohm-cm (white) (20°C)
**Ionization potential (1st):** 10.486 eV
**Oxidation potential:** $P + 2H_2O \rightarrow H_3PO_2 + H^+ + \epsilon = 0.508$ V
**Chemical valence:** $-3, 3, 5$
**Electrochemical equivalents:** 0.23113 g/amp-hr
**Ionic radius:** 0.38 Å ($P^{5+}$)
**Valence electron potential ($-\varepsilon$V):** 190
**Principal quantum number:** 3
**Principal electron shells:** K L M
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$
**Valence electrons:** $3s^2\ 3p^3$
**Crystal form:** Cubic
**Cross section $\sigma$:** 0.19 barns
**Vapor pressure:** 20.8 Pa (at melting point)

Four allotropes of phosphorus have different melting points, crystal forms, colors, and electrical conductivities. The black variety has the highest electrical conductivity.

# Pt Platinum

78

195.09




**Platina**
**Platine**
**Plátin**
**Platino**
**платина**
**פלטין**
**鉑 白金[プラチナ]**

**Naturally occurring isotopes:** 195, 194, 196, 198, 192, 190
**Density:** 21.45 g/cm$^3$ (20°C)
**Melting point:** 1773.5°C **Boiling point:** 3827 ± 100°C
**Latent heat of fusion:** 100.9 J/g
**Specific heat:** 0.133 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 9.5 × $10^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 0.716 w/cm/°C (25°C)
**Electrical resistivity:** 9.85 × $10^{-6}$ ohm-cm (0°C)
**Ionization potential (1st):** 8.96 eV
**Electron work function $\phi$:** 5.65 eV
**Oxidation potential:** $Pt \rightarrow Pt^{2+} + 2\epsilon = -1.2$ V
**Chemical valence:** 2, 3, *4*
**Electrochemical equivalents:** 1.8197 g/amp-hr
**Ionic radius:** 0.625 Å ($Pt^{4+}$)
**Valence electron potential ($-\varepsilon$V):** 92.2
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^9\ 6s^1$
**Valence electrons:** $5d^9\ 6s^1$
**Crystal form:** Cubic, face centered
**Cross section $\sigma$:** 9 ± 1 barns
**Vapor pressure:** 3.12 × $10^{-2}$ Pa (at melting point)

# Pu Plutonium

94

244.06423

Actinide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 232.03807 Th 90 | 231.0359 Pa 91 | 238.029 U 92 | 237.0482 Np 93 | 244.06423 Pu 94 | 243.0614 Am 95 | 247.07038 Cm 96 | 247.07032 Bk 97 | 251.07961 Cf 98 | 254.08805 Es 99 |
| 257.09515 Fm 100 | 258 Md 101 | 259 No 102 | 260 Lr 103 | | | | | | |

**Plutônio**
**Plutonium**
**Plutonium**
**Plutonio**
**плутоний**
**פלוטוניום**
鈽 プリトニウム

**Naturally occurring isotope:** 242 (trace)
**Density:** 19.737 g/cm$^3$ (25°C)
**Melting point:** 639.5°C **Boiling point:** 3232°C
**Latent heat of fusion:** 11 J/g
**Specific heat:** 0.14 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 42.3 × 10$^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 0.0670 w/cm/°C (25°C)
**Electrical resistivity:** 146.45 × 10$^{-6}$ ohm-cm (0°C)
**Ionization potential (1st):** 6.06 eV
**Oxidation potential:** $Pu \rightarrow Pu^{3+} + 3\epsilon = 2.031$ V
**Chemical valence:** 3, *4,* 5, 6, 7
**Electrochemical equivalents:** 2.2765 g/amp-hr
**Ionic radius:** 0.887 Å ($Pu^{4+}$)
**Valence electron potential (−εV):** 64.9
**Principal quantum number:** 7
**Principal electron shells:** K L M N O P Q
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 5f^6\ 6s^2\ 6p^6\ 7s^2$
**Valence electrons:** $5f^6\ 7s^2$
**Crystal form:** Monoclinic
**Half life:** 8.3 × 10$^7$ years
**Cross section σ:** 1.8 ± 0.3 barns

# Po Polonium

84

208.98243

VIA

| |
|---|
| 15.9994<br>O<br>8 |
| 32.06<br>S<br>16 |
| 78.96<br>Se<br>34 |
| 127.60<br>Te<br>52 |
| 208.98243<br>Po<br>84 |

Polônio
Polonium
Polonium
Polonio
полоний
פולוניום
钋 ポロニウム

**Naturally occurring isotopes:** None
**Density:** 9.20 g/cm$^3$ (20°C)
**Melting point:** 254°C **Boiling point:** 962°C
**Latent heat of fusion:** 60.1 J/g
**Specific heat:** 0.13 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 23.5 × $10^{-6}$ cm/cm/°C (20°C)
**Electrical resistivity:** 42 × $10^{-6}$ ohm-cm (0°C)
**Ionization potential (1st):** 8.42 eV
**Oxidation potential:** $Po \rightarrow Po^{2+} + 2\epsilon = -0.65$ V
**Chemical valence:** *−2,* 0, 2, 4, 6
**Electrochemical equivalents:** 3.8986 g/amp-hr
**Ionic radius:** 2.30 Å ($Po^{2-}$)
**Valence electron potential (−εV):** −12.5
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 6s^2\ 6p^4$
**Valence electrons:** $6s^2\ 6p^4$
**Crystal form:** Cubic, body centered
**Half life:** 103 years
**Vapor pressure:** 1.76 × $10^{-2}$ Pa (at melting point)

# K Potassium

19

39.098

IA

| |
|---|
| 1.0079 H 1 |
| 6.941 Li 3 |
| 22.98977 Na 11 |
| 39.098 K 19 |
| 85.4678 Rb 37 |
| 132.9054 Cs 55 |
| 223.01976 Fr 87 |

**Potássio**
**Potassium**
**Kalium**
**Potasio**
**калий**
**אשלגן**
**鉀** カリウム

**Naturally occurring isotopes:** 39, 41, 40
**Density:** 0.862 g/cm$^3$ (20°C)
**Melting point:** 63.25°C **Boiling point:** 759.9°C
**Latent heat of fusion:** 59.33 J/g
**Specific heat:** 0.757 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 83 $\times$ $10^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 1.025 w/cm/°C (25°C)
**Electrical resistivity:** 7.20 $\times$ $10^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 4.341 eV
**Electron work function $\phi$:** 2.30 eV
**Oxidation potential:** $K \rightarrow K^+ + \epsilon = 2.925$ V
**Chemical valence:** 1
**Electrochemical equivalents:** 1.4587 g/amp-hr
**Ionic radius:** 1.38 Å ($K^+$)
**Valence electron potential ($-\varepsilon$V):** 10.4
**Principal quantum number:** 4
**Principal electron shells:** K L M N
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$
**Valence electrons:** $4s^1$
**Crystal form:** Cubic, body centered
**Cross section $\sigma$:** 2.1 barns
**Vapor pressure:** 1.06 $\times$ $10^{-4}$ Pa (at melting point)

# Pr Praseodymium

59

140.9077

Lanthanide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 140.12 Ce 58 | 140.9077 Pr 59 | 144.24 Nd 60 | 144.913 Pm 61 | 150.4 Sm 62 | 151.96 Eu 63 | 157.25 Gd 64 | 158.9254 Tb 65 | 162.50 Dy 66 | 164.9304 Ho 67 |
| 167.26 Er 68 | 168.9342 Tm 69 | 173.04 Yb 70 | 174.97 Lu 71 | | | | | | |

**Praséodímio**
**Praseodyne**
**Praseodym**
**Praseodimio**
**празеодимий**
**פרסיאודום**
**鐠 プラセオジム**

**Naturally occurring isotope:** 141
**Density:** 6.773 g/cm$^3$ (25°C)
**Melting point:** 931°C **Boiling point:** 3512°C
**Latent heat of fusion:** 71.3 J/g
**Specific heat:** 0.193 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 6.5 × 10$^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 0.125 w/cm/°C (25°C)
**Electrical resistivity:** 68 × 10$^{-6}$ ohm-cm (25°C)
**Ionization potential (1st):** 5.42 eV
**Electron work function** $\phi$**:** 2.7 eV
**Oxidation potential:** $Pr \rightarrow Pr^{3+} + 3\epsilon = 2.462$ V
**Chemical valence:** *3,* 4
**Electrochemical equivalents:** 1.7524 g/amp-hr
**Ionic radius:** 1.013 Å ($Pr^{3+}$)
**Valence electron potential (**$-\varepsilon$**V):** 42.64
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^3\ 5s^2\ 5p^6\ 6s^2$
**Valence electrons:** $4f^3\ 6s^2$
**Crystal form:** Hexagonal, close packed
**Cross section** $\sigma$**:** 3.9 ± 0.5 barns

# Pm Promethium

61

144.913

Lanthanide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 140.12 Ce 58 | 140.9077 Pr 59 | 144.24 Nd 60 | 144.913 Pm 61 | 150.4 Sm 62 | 151.96 Eu 63 | 157.25 Gd 64 | 158.9254 Tb 65 | 162.50 Dy 66 | 164.9304 Ho 67 |
| 167.26 Er 68 | 168.9342 Tm 69 | 173.04 Yb 70 | 174.97 Lu 71 | | | | | | |

**Promécio**
**Prometheum**
**Prometheum**
**Promecio**
**прометий**
**פרומתיום**
鉕 プロメチウム

**Naturally occurring isotopes:** None
**Density:** $7.22 \pm 0.02$ g/cm$^3$ (25°C)
**Melting point:** $1168 \pm 6$°C **Boiling point:** 2460°C
**Latent heat of fusion:** 86.7 J/g
**Specific heat:** 0.185 J/g/°C (25°C)
**Thermal conductivity:** 0.179 w/cm/°C (25°C)
**Ionization potential (1st):** 5.55 eV
**Oxidation potential:** $Pm \rightarrow Pm^{3+} + 3\epsilon = 2.423$ V
**Chemical valence:** 3
**Electrochemical equivalents:** 1.8022 g/amp-hr
**Ionic radius:** 0.979 Å ($Pm^{3+}$)
**Valence electron potential ($-\epsilon$V):** 44.1
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^5\ 5s^2\ 5p^6\ 6s^2$
**Valence electrons:** $4f^5\ 6s^2$
**Crystal form:** Hexagonal
**Half life:** 17.7 years

# Pa Protactinium

91

231.0359

Actinide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 232.03807 Th 90 | 231.0359 Pa 91 | 238.029 U 92 | 237.0482 Np 93 | 244.06423 Pu 94 | 243.0614 Am 95 | 247.07038 Cm 96 | 247.07032 Bk 97 | 251.07961 Cf 98 | 254.08805 Es 99 |
| 257.09515 Fm 100 | 258 Md 101 | 259 No 102 | 260 Lr 103 | | | | | | |

**Protactínio**
**Protactinium**
**Protactinium**
**Protactinio**
**протактиний**
**פרוטאקטיניום**
鏷 **プロトアクチニウム**

**Naturally occurring isotope:** 231 (minute quantities only)
**Density:** 15.37 g/cm$^3$ (25°C)
**Melting point:** 1575°C
**Latent heat of fusion:** 65 J/g
**Specific heat:** 0.12 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 11.2 × $10^{-6}$ cm/cm/°C (25°C)
**Ionization potential (1st):** 5.89 eV
**Chemical valence:** 3, 4, *5*
**Electrochemical equivalents:** 1.7240 g/amp-hr
**Oxidation potential:** $Pa \rightarrow Pa^{3+} + 3\epsilon = 1.6$ V
**Ionic radius:** 0.78 Å ($Pa^{5+}$)
**Valence electron potential (−εV):** 92
**Principal quantum number:** 7
**Principal electron shells:** K L M N O P Q
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 5f^2\ 6s^2\ 6p^6\ 6d^1\ 7s^2$
**Valence electrons:** $5f^2\ 6d^1\ 7s^2$
**Crystal form:** Tetragonal
**Half life:** 3.248 × $10^4$ years
**Cross section σ:** 200 ± 10 barns

# Ra Radium

88

226.02544

IIA

| |
|---|
| 9.01218<br>Be<br>4 |
| 24.305<br>Mg<br>12 |
| 40.08<br>Ca<br>20 |
| 87.62<br>Sr<br>38 |
| 137.34<br>Ba<br>56 |
| 226.02544<br>Ra<br>88 |

**Rádio**
**Radium**
**Radium**
**Radio**
**радий**
**רדיום**
鐳 ラジウム

**Naturally occurring isotope:** 226 (minute quantities only)
**Density:** 5.5 g/cm$^3$ (extrapolated) (20°C)
**Melting point:** 700°C **Boiling point:** 1140°C
**Latent heat of fusion:** 37 J/g (est)
**Specific heat:** 0.120 J/g/°C (25°C)
**Thermal conductivity:** 0.186 w/cm/°C (20°C)
**Ionization potential (1st):** 5.279 eV
**Oxidation potential:** $Ra \rightarrow Ra^{2+} + 2\epsilon = 2.916$ V
**Chemical valence:** 2
**Electrochemical equivalents:** 4.2165 g/amp-hr
**Ionic radius:** 1.43 Å ($Ra^{2+}$)
**Valence electron potential ($-\varepsilon$V):** 20.1
**Principal quantum number:** 7
**Principal electron shells:** K L M N O P Q
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 6s^2\ 6p^6\ 7s^2$
**Valence electrons:** $7s^2$
**Half life:** 1622 years
**Cross section $\sigma$:** $20 \pm 3$ barns
**Vapor pressure:** $3.27 \times 10^2$ Pa (at melting point)

# Rn Radon

86

222.01761

O

| |
|---|
| 4.00260 He 2 |
| 20.179 Ne 10 |
| 39.948 Ar 18 |
| 83.80 Kr 36 |
| 131.30 Xe 54 |
| 222.01761 Rn 86 |

**Radônio**
**Radon**
**Radon**
**Radòn**
**радон**
**ראדון**
**氡 ラドン**

**Naturally occurring isotopes:** None (radium decay product)
**Density:** $9.96 \times 10^{-3}$ g/cm$^3$ (20°C)
**Melting point:** −71°C **Boiling point:** −61.8°C
**Latent heat of fusion:** 13.1 J/g
**Specific heat:** 0.09362 J/g/°C (25°C)
**Thermal conductivity:** 0.0364 mw/cm/°C (27°C)
**Ionization potential (1st):** 10.748 eV
**Chemical valence:** 0
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 6s^2\ 6p^6$
**Valence electrons:** ($6s^2\ 6p^6$)
**Crystal form:** Cubic, face centered
**Half life:** 3.824 days
**Cross section σ:** $0.72 \pm 0.07$ barns

# Re Rhenium

75

186.2

VIIB

| |
|---|
| 54.9380<br>Mn<br>25 |
| 96.906<br>Tc<br>43 |
| 186.2<br>Re<br>75 |
| 107 |

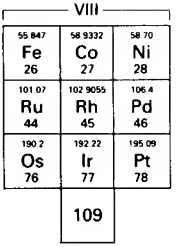
Rênio
Rhenium
Rhenium
Renio
рений
רניום
錸 レニウム

**Naturally occurring isotopes:** 187, 185
**Density:** 21.04 g/cm$^3$ (20°C)
**Melting point:** 3180°C **Boiling point:** 5627°C (est)
**Latent heat of fusion:** 177.6 J/g
**Specific heat:** 0.137 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 6.7 $\times$ $10^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 0.480 w/cm/°C (25°C)
**Electrical resistivity:** 19.3 $\times$ $10^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 7.88 eV
**Electron work function $\phi$:** 4.96 eV
**Oxidation potential:** $Re + 2H_2O \rightarrow ReO_2 + 4H^+ + 4\epsilon = -0.2513$ V
**Chemical valence:** 0, 1, 2, 3, 4, 5, 6, 7
**Electrochemical equivalents:** 0.9924 g/amp-hr
**Ionic radius:** 0.56 Å ($Re^{7+}$)
**Valence electron potential ($-\varepsilon$V):** 180
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^5\ 6s^2$
**Valence electrons:** $5d^5\ 6s^2$
**Crystal form:** Hexagonal, close packed
**Cross section $\sigma$:** 85 $\pm$ 5 barns
**Vapor pressure:** 3.24 Pa (at melting point)

# Rh Rhodium

45

102.9055




**Ródio**
**Rhodium**
**Rhodium**
**Rodio**
**родий**
**רודיום**
銠 ロジウム

**Naturally occurring isotope:** 103
**Density:** 12.41 g/cm$^3$ (20°C)
**Melting point:** 1966 ± 3°C **Boiling point:** 3727 ± 100°C
**Latent heat of fusion:** 211.6 J/g
**Specific heat:** 0.24 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 8.3 × 10$^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 1.50 w/cm/°C (25°C)
**Electrical resistivity:** 4.51 × 10$^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 7.46 eV
**Electron work function** $\phi$**:** 4.98 eV
**Oxidation potential:** $Rh \rightarrow Rh^{3+} + 3\epsilon = -0.80$ V
**Chemical valence:** 2, *3,* 4, 5, 6
**Electrochemical equivalents:** 1.2798 g/amp-hr
**Ionic radius:** 0.68 Å ($Rh^{3+}$)
**Valence electron potential (**$-\varepsilon$**V):** 64
**Principal quantum number:** 5
**Principal electron shells:** K L M N O
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^8\ 5s^1$
**Valence electrons:** $4d^8\ 5s^1$
**Crystal form:** Cubic, face centered
**Cross section** $\sigma$**:** 150 ± 5 barns
**Vapor pressure:** 6.33 × 10$^{-1}$ Pa (at melting point)

# Rb Rubidium

37

85.4678

IA

| |
|---|
| 1.0079 H 1 |
| 6.941 Li 3 |
| 22.98977 Na 11 |
| 39.098 K 19 |
| 85.4678 Rb 37 |
| 132.9054 Cs 55 |
| 223.01976 Fr 87 |

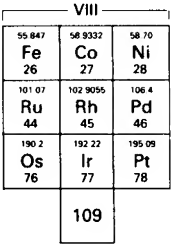
Rubidio
Rubidium
Rubidium
Rubidio
рубидий
רוביידיום
鈉 ルビジウム

**Naturally occurring isotopes:** 85, 87
**Density:** 1.532 g/cm$^3$ (20°C)
**Melting point:** 38.89°C **Boiling point:** 686°C
**Latent heat of fusion:** 27.43 J/g
**Specific heat:** 0.3634 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 90 × $10^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 0.582 w/cm/°C (25°C)
**Electrical resistivity:** 12.84 × $10^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 4.177 eV
**Electron work function $\phi$:** 2.16 eV
**Oxidation potential:** $Rb \rightarrow Rb^+ + \epsilon = 2.925$ V
**Chemical valence:** 1
**Electrochemical equivalents:** 3.1888 g/amp-hr
**Ionic radius:** 1.52 Å ($Rb^+$)
**Valence electron potential ($-\varepsilon$V):** 9.47
**Principal quantum number:** 5
**Principal electron shells:** K L M N O
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 5s^1$
**Valence electrons:** $5s^1$
**Crystal form:** Cubic, body centered
**Cross section $\sigma$:** 0.5 ± 0.1 barns
**Vapor pressure:** 1.56 × $10^{-4}$ Pa (at melting point)

# Ru Ruthenium

44

101.07




**Rutênio**
**Ruthénium**
**Ruthenium**
**Rutenio**
**рутений**
**רותניום**
釘 ルテニウム

**Naturally occurring isotopes:** 102, 104, 101, 99, 100, 96, 98
**Density:** 12.45 g/cm$^3$ (20°C)
**Melting point:** 2310°C **Boiling point:** 3900°C
**Latent heat of fusion:** 252.7 J/g
**Specific heat:** 0.238 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 9.91 × $10^{-6}$ cm/cm/°C (50°C)
**Thermal conductivity:** 1.17 w/cm/°C (25°C)
**Electrical resistivity:** 6.80 × $10^{-6}$ ohm-cm (0°C)
**Ionization potential (1st):** 7.37 eV
**Electron work function** $\phi$**:** 4.71 eV
**Oxidation potential:** $Ru + 5Cl^- \rightarrow RuCl_3^{2-} + 3\epsilon = -0.601$ V
**Chemical valence:** 1, 2, *3,* 4, 5, 6, 7, 8
**Electrochemical equivalents:** 1.2570 g/amp-hr
**Ionic radius:** 0.68 Å ($Ru^{4+}$)
**Valence electron potential (**$-\varepsilon$**V):** 64
**Principal quantum number:** 5
**Principal electron shells:** K L M N O
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^7\ 5s^1$
**Valence electrons:** $4d^7\ 5s^1$
**Crystal form:** Hexagonal, close packed
**Cross section** $\sigma$**:** 3.0 ± 0.8 barns
**Vapor pressure:** 1.40 Pa (at melting point)

# Sm Samarium

62

150.4

Lanthanide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 140.12 Ce 58 | 140.9077 Pr 59 | 144.24 Nd 60 | 144.913 Pm 61 | 150.4 Sm 62 | 151.96 Eu 63 | 157.25 Gd 64 | 158.9254 Tb 65 | 162.50 Dy 66 | 164.9304 Ho 67 |
| 167.26 Er 68 | 168.9342 Tm 69 | 173.04 Yb 70 | 174.97 Lu 71 | | | | | | |

**Samário**
**Samarium**
**Samarium**
**Samario**
**самарий**
**סמריום**
**鉑 サマリウム**

**Naturally occurring isotopes:** 152, 154, 147, 149, 148, 150, 144
**Density:** 7.520 g/cm$^3$ (25°C)
**Melting point:** 1077°C **Boiling point:** 1791°C
**Latent heat of fusion:** 73.8 J/g
**Specific heat:** 0.196 J/g/°C (25°C)
**Thermal conductivity:** 0.133 w/cm/°C (25°C)
**Electrical resistivity:** 88 × $10^{-6}$ ohm-cm (25°C)
**Ionization potential (1st):** 5.63 eV
**Electron work function** $\phi$**:** 2.7 eV
**Oxidation potential:** $Sm \rightarrow Sm^{3+} + 3\epsilon = 2.414$ V
**Chemical valence:** 2, *3*
**Electrochemical equivalents:** 1.870 g/amp-hr
**Ionic radius:** 0.964 Å ($Sm^{3+}$)
**Valence electron potential (**$-\varepsilon$**V):** 44.8
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^6\ 5s^2\ 5p^6\ 6s^2$
**Valence electrons:** $4f^6\ 6s^2$
**Crystal form:** Rhombohedral
**Cross section** $\sigma$**:** 5820 ± 100 barns
**Vapor pressure:** 5.63 × $10^2$ Pa (at melting point)

# Sc Scandium

21

44.95592

IIIB

| 44.95592 |
|---|
| Sc |
| 21 |
| 88.9059 |
| Y |
| 39 |
| 138.9055 |
| La |
| 57 |
| 227.02777 |
| Ac |
| 89 |

Escândio
Scandium
Scandium
Escandio
скандий
סקנדיום
鈧 スカンヅウム

**Naturally occurring isotope:** 45
**Density:** 2.989 g/cm$^3$ (25°C)
**Melting point:** 1541°C **Boiling point:** 2831°C
**Latent heat of fusion:** 358.6 J/g
**Specific heat:** 0.568 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 12 × 10$^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 0.158 w/cm/°C (25°C)
**Electrical resistivity:** 61.0 × 10$^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 6.54 eV
**Electron work function $\phi$:** 3.5 eV
**Oxidation potential:** $Sc \rightarrow Sc^{3+} + 3\epsilon = 2.077$ V
**Chemical valence:** 3
**Electrochemical equivalents:** 0.55914 g/amp-hr
**Ionic radius:** 0.745 Å ($Sc^{3+}$)
**Valence electron potential ($-\varepsilon$V):** 58.0
**Principal quantum number:** 4
**Principal electron shells:** K L M N
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^1\ 4s^2$
**Valence electrons:** $3d^1\ 4s^2$
**Crystal form:** Hexagonal, close packed
**Cross section $\sigma$:** 25 ± 2 barns
**Vapor pressure:** 2.21 × 10 Pa (at melting point)

# Se Selenium

34

78.96

VIA

| |
|---|
| 15.9994<br>O<br>8 |
| 32.06<br>S<br>16 |
| 78.96<br>Se<br>34 |
| 127.60<br>Te<br>52 |
| 208.98243<br>Po<br>84 |

**Selênio**
**Sélénium**
**Selen**
**Selenio**
**селен**
**סלן**
硒 セレン

**Naturally occurring isotopes:** 80, 78, 82, 76, 77, 74
**Density:** 4.792 g/cm$^3$ (gray) (20°C)
**Melting point:** 217°C (gray) **Boiling point:** 684.9 ± 1.0°C
**Latent heat of fusion:** 68.93 J/g
**Specific heat:** 0.1606 J/g/°C ($Se_2$) (25°C)
**Coefficient of lineal thermal expansion:** 36.8 cm/cm/°C (20°C)
**Thermal conductivity:** 0.0452 w/cm/°C (along C-axis at 25°C)
**Electrical resistivity:** 1 ohm-cm (20°C)
**Ionization potential (1st):** 9.752 eV
**Electron work function** $\phi$**:** 5.9 eV
**Oxidation potential:** $Se + 3H_2O \rightarrow H_2SeO_3 + 4H^+ + 4\epsilon = -0.740$ V
**Chemical valence:** −2, *4,* 6
**Electrochemical equivalents:** 0.73650 g/amp-hr
**Ionic radius:** 0.50 Å ($Se^{4+}$)
**Valence electron potential (**$-\varepsilon$**V):** 120
**Principal quantum number:** 4
**Principal electron shells:** K L M N
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^4$
**Valence electrons:** $4s^2\ 4p^4$
**Crystal forms:** Hexagonal, monoclinic, amorphous
**Cross section** $\sigma$**:** 12.2 ± 0.6 barns
**Vapor pressure:** $6.95 \times 10^{-1}$ Pa (at melting point)

# Si Silicon

14

28.0855

IVA

| |
|---|
| 12.011<br>C<br>6 |
| 28.0855<br>Si<br>14 |
| 72.59<br>Ge<br>32 |
| 118.69<br>Sn<br>50 |
| 207.2<br>Pb<br>82 |

**Silício**
**Silicium**
**Silizium**
**Silicio**
**кремний**
**צורן**
硅 珪素

**Naturally occurring isotopes:** 28, 29, 30
**Density:** 2.329 g/cm$^3$ (25°C)
**Melting point:** 1410°C **Boiling point:** 2355°C
**Latent heat of fusion:** 1.655 J/g
**Specific heat:** 0.712 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 4.2 $\times$ $10^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 1.49 w/cm/°C (25°C)
**Electrical resistivity:** 3.5 ohm-cm (20°C)
**Ionization potential (1st):** 8.151 eV
**Electron work function $\phi$:** 4.52 eV
**Oxidation potential:** $Si + 2H_2O \rightarrow SiO_2 + 4H^+ + 4\epsilon = 0.857$ V
**Chemical valence:** $-4, -1, 1, \mathit{4}$
**Electrochemical equivalents:** 0.26197 g/amp-hr
**Ionic radius:** 0.400 Å ($Si^{4+}$)
**Valence electron potential ($-\varepsilon$V):** 144
**Principal quantum number:** 3
**Principal electron shells:** K L M
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$
**Valence electrons:** $3s^2\ 3p^2$
**Crystal form:** Cubic, diamond
**Cross section $\sigma$:** 160 $\pm$ 20 mbarns
**Vapor pressure:** 4.77 Pa (at melting point)

# Ag Silver

47

107.868

IB

| 63.546 |
|---|
| Cu |
| 29 |
| 107.868 |
| Ag |
| 47 |
| 196.9665 |
| Au |
| 79 |

Prata
Argent
Silber
Plata
серебро
כסף
銀 銀

**Naturally occurring isotopes:** 107, 109
**Density:** 10.50 g/cm$^3$ (20°C)
**Melting point:** 961.93°C **Boiling point:** 2212°C
**Latent heat of fusion:** 104.8 J/g
**Specific heat:** 0.2350 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 18.62 $\times$ 10$^{-6}$ cm/cm/°C (17°C)
**Thermal conductivity:** 4.29 w/cm/°C (25°C)
**Electrical resistivity:** 1.586 $\times$ 10$^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 7.576 eV
**Electron work function $\phi$:** 4.26 eV
**Oxidation potentials:** $Ag \rightarrow Ag^+ + \epsilon = -0.7991$ V
$Ag^+ \rightarrow Ag^{2+} + \epsilon = -1.980$ V
**Chemical valence:** *1*, 2, 3
**Electrochemical equivalents:** 4.0246 g/amp-hr
**Ionic radius:** 1.26 Å ($Ag^+$)
**Valence electron potential ($-\varepsilon$V):** 11.4
**Principal quantum number:** 5
**Principal electron shells:** K L M N O
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 5s^1$
**Valence electrons:** $(4d^{10})\ 5s^1$
**Crystal form:** Cubic, face centered
**Cross section $\sigma$:** 63.8 $\pm$ 0.6 barns
**Vapor pressure:** 3.42 $\times$ 10$^{-1}$ Pa (at melting point)

# Na Sodium

11

22.98977

IA

| |
|---|
| 1.0079 H 1 |
| 6.941 Li 3 |
| 22.98977 Na 11 |
| 39.098 K 19 |
| 85.4678 Rb 37 |
| 132.9054 Cs 55 |
| 223.01976 Fr 87 |

Sódio
Sodium
Natrium
Sodio
натрий
נתרן
鈉 ナトリウム

**Naturally occurring isotopes:** 23
**Density:** 0.9712 g/cm$^3$ (20°C)
**Melting point:** 97.81 ± 0.03°C **Boiling point:** 882.9°C
**Latent heat of fusion:** 113 J/g
**Specific heat:** 1.23 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 72 × $10^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 1.42 w/cm/°C (25°C)
**Electrical resistivity:** 4.33 × $10^{-6}$ ohm-cm (0°C)
**Ionization potential (1st):** 5.139 eV
**Electron work function $\phi$:** 2.75 eV
**Oxidation potential:** $Na \rightarrow Na^+ + \epsilon = 2.714$ V
**Chemical valence:** 1
**Electrochemical equivalents:** 0.85775 g/amp-hr
**Ionic radius:** 1.02 Å ($Na^+$)
**Valence electron potential ($-\varepsilon$V):** 14.1
**Principal quantum number:** 3
**Principal electron shells:** K L M
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^1$
**Valence electrons:** $3s^1$
**Crystal form:** Cubic, body centered
**Cross section $\sigma$:** 534 ± 5 mbarns
**Vapor pressure:** 1.43 × $10^{-5}$ Pa (at melting point)

# Sr Strontium

38

87.62

IIA

| |
|---|
| 9.01218 Be 4 |
| 24.305 Mg 12 |
| 40.08 Ca 20 |
| 87.62 Sr 38 |
| 137.34 Ba 56 |
| 226.02544 Ra 88 |

Estrôncio
Strontium
Strontium
Estroncio
стронций
סטרונציום
鍶 ストロンチウム

**Naturally occurring isotopes:** 88, 86, 87, 84
**Density:** 2.54 g/cm$^3$ (20°C)
**Melting point:** 769°C **Boiling point:** 1384°C
**Latent heat of fusion:** 105.1 J/g
**Specific heat:** 0.30 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 21 × 10$^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 0.354 w/cm/°C (25°C)
**Electrical resistivity:** 23 × 10$^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 5.695 eV
**Electron work function $\phi$:** 2.59 eV
**Oxidation potential:** $Sr \rightarrow Sr^{2+} + 2\epsilon = 2.888$ V
**Chemical valence:** 2
**Electrochemical equivalents:** 1.635 g/amp-hr
**Ionic radius:** 1.12 Å ($Sr^{2+}$)
**Valence electron potential ($-\epsilon V$):** 25.7
**Principal quantum number:** 5
**Principal electron shells:** K L M N O
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 5s^2$
**Valence electrons:** $5s^2$
**Crystal form:** Cubic, face centered
**Cross section $\sigma$:** 1.21 ± 0.06 barns
**Vapor pressure:** 2.46 × 10$^2$ Pa (at melting point)

# Sulfur

16

32.06

VIA

| |
|---|
| 15.9994<br>O<br>8 |
| 32.06<br>S<br>16 |
| 78.96<br>Se<br>34 |
| 127.60<br>Te<br>52 |
| 208.98243<br>Po<br>84 |

**Enxôfre**
**Soufre**
**Schwefel**
**Azufre**
**cepa**
**גפרית**
硫 硫黄

**Naturally occurring isotopes:** 32, 34, 33, 36
**Density:** 2.07 g/cm$^3$ (rhombic form at 25°C)
**Melting point:** 112.8°C **Boiling point:** 444.674°C
**Latent heat of fusion:** 44.01 J/g
**Specific heat:** 0.706 J/g/°C (rhombic) (25°C)
**Coefficient of lineal thermal expansion:** 64.13 × $10^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 2.70 mw/cm/°C (25°C)
**Electrical resistivity:** 2 × $10^{17}$ ohm-cm (20°C)
**Ionization potential (1st):** 10.360 eV
**Oxidation potentials:** $S + 3H_2O \rightarrow H_2SO_3 + 4H^+ + 4\epsilon = -0.45$ V
$S^{2-} \rightarrow S + 2\epsilon = 0.447$ V
**Chemical valence:** −2, *4*, 6
**Electrochemical equivalents:** 0.2990 g/amp-hr
**Ionic radius:** 0.37 Å ($S^{4+}$)
**Valence electron potential (−εV):** 160
**Principal quantum number:** 3
**Principal electron shells:** K L M
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$
**Valence electrons:** $3s^2\ 3p^4$
**Crystal form:** Orthorhombic
**Cross section σ:** 0.51 barns
**Vapor pressure:** 2.65 × $10^{-20}$ Pa (at melting point)

# Ta Tantalum

73

180.9479

VB

| |
|---|
| 50.9415 V 23 |
| 92.9064 Nb 41 |
| 180.9479 Ta 73 |
| 105 |

Tantálio
Tantale
Tantal
Tántalo
тантал
טנטל
鉭 タンタル

**Naturally occurring isotopes:** 181, 180
**Density:** 16.60 g/cm$^3$ (20°C)
**Melting point:** 2996°C **Boiling point:** 5425 ± 100°C
**Latent heat of fusion:** 174 J/g
**Specific heat:** 0.140 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 6.5 × $10^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 0.575 w/cm/°C (25°C)
**Electrical resistivity:** 12.45 × $10^{-6}$ ohm-cm (25°C)
**Ionization potential (1st):** 7.89 eV
**Electron work function** $\phi$**:** 4.25 eV
**Oxidation potential:** $2Ta + 5H_2O \rightarrow Ta_2O_5 + 10H^+ + 10\epsilon = 0.812$ V
**Chemical valence:** 3, 4, *5*
**Electrochemical equivalents:** 1.3502 g/amp-hr
**Ionic radius:** 0.64 Å ($Ta^{5+}$)
**Valence electron potential (**$-\varepsilon$**V):** 110
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^3\ 6s^2$
**Valence electrons:** $5d^3\ 6s^2$
**Crystal form:** Cubic, body centered
**Cross section** $\sigma$**:** 22 ± 1 barns
**Vapor pressure:** 7.76 × $10^{-1}$ Pa (at melting point)

# Tc Technetium

43

96.906

VIIB

| |
|---|
| 54.9380<br>Mn<br>25 |
| 96.906<br>Tc<br>43 |
| 186.2<br>Re<br>75 |
| 107 |

Tecnécio
Technetium
Technetium
Tecnecio
технеций
טכנציום
鍀 テクネチウム

**Naturally occurring isotopes:** None
**Density:** 11.496 g/cm$^3$ (25°C)
**Melting point:** 2172°C **Boiling point:** 4877°C
**Latent heat of fusion:** 235 ± 5 J/g
**Specific heat:** 0.24 J/g/°C (25°C)
**Thermal conductivity:** 0.506 w/cm/°C (25°C)
**Ionization potential (1st):** 7.28 eV
**Oxidation potential:** $Tc \rightarrow Tc^{2+} + 2\epsilon = -0.4$ V
**Chemical valence:** 0, 1, 2, 3, 4, 5, 6, 7
**Electrochemical equivalents:** 0.51651 g/amp-hr
**Ionic radius:** 0.56 Å ($Tc^{7+}$)
**Valence electron potential (−εV):** 180
**Principal quantum number:** 5
**Principal electron shells:** K L M N O
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^6\ 5s^1$
**Valence electrons:** $4d^6\ 5s^1$
**Crystal form:** Hexagonal, close packed
**Half life:** $2.6 \times 10^6$ years
**Vapor pressure:** $2.29 \times 10^{-2}$ Pa (at melting point)

# Te Tellurium

52

127.60

VIA

| |
|---|
| 15.9994<br>O<br>8 |
| 32.06<br>S<br>16 |
| 78.96<br>Se<br>34 |
| 127.60<br>Te<br>52 |
| 208.98243<br>Po<br>84 |

**Telúrio**
**Tellure**
**Tellur**
**Telurio**
**теллур**
**טלור**
碲 テルル

**Naturally occurring isotopes:** 130, 128, 126, 125, 124, 122, 123
**Density:** 6.24 g/cm$^3$ (20°C)
**Melting point:** 449.5 ± 0.3°C **Boiling point:** 989.8 ± 3.8°C
**Latent heat of fusion:** 137.2 J/g
**Specific heat:** 0.202 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 16.75 × $10^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 0.0338 w/cm/°C (along C-axis at 25°C)
**Electrical resistivity:** 4.36 ohm-cm (25°C)
**Ionization potential (1st):** 0.009 eV
**Electron work function** $\phi$**:** 4.95 eV
**Oxidation potential:** $Te + 2H_2O \rightarrow TeO_2 + 4H^+ + 4\epsilon = -0.529$ V
**Chemical valence:** −2, 2, *4,* 6
**Electrochemical equivalents:** 1.1902 g/amp-hr
**Ionic radius:** 0.97 Å ($Te^{4+}$)
**Valence electron potential (**$-\varepsilon$**V):** 59
**Principal quantum number:** 5
**Principal electron shells:** K L M N O
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 5s^2\ 5p^4$
**Valence electrons:** $5s^2\ 5p^4$
**Crystal form:** Hexagonal
**Cross section** $\sigma$**:** 4.7 ± 0.1 barns
**Vapor pressure:** 2.31 × 10 Pa (at melting point)

# Tb Terbium

65

158.9254

Lanthanide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 140.12 Ce 58 | 140.9077 Pr 59 | 144.24 Nd 60 | 144.913 Pm 61 | 150.4 Sm 62 | 151.96 Eu 63 | 157.25 Gd 64 | 158.9254 Tb 65 | 162.50 Dy 66 | 164.9304 Ho 67 |
| 167.26 Er 68 | 168.9342 Tm 69 | 173.04 Yb 70 | 174.97 Lu 71 | | | | | | |

**Térbio**
**Terbium**
**Terbium**
**Terbio**
**тербий**
**טרביום**
鉞 テルビウム

**Naturally occurring isotope:** 159
**Density:** 8.229 g/cm$^3$ (25°C)
**Melting point:** 1356°C **Boiling point:** 3123°C
**Latent heat of fusion:** 102.7 J/g
**Specific heat:** 0.182 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 11.8 × 10$^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 0.111 w/cm/°C (25°C)
**Electrical resistivity:** 116 × 10$^{-6}$ ohm-cm (25°C)
**Ionization potential (1st):** 5.85 eV
**Electron work function $\phi$:** 3.0 eV
**Oxidation potential:** Tb → Tb$^{3+}$ + 3$\epsilon$ = 2.391 V
**Chemical valence:** *3,* 4
**Electrochemical equivalents:** 1.9765 g/amp-hr
**Ionic radius:** 0.923 Å (Tb$^{3+}$)
**Valence electron potential (−$\varepsilon$V):** 46.8
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** 1s$^2$ 2s$^2$ 2p$^6$ 3s$^2$ 3p$^6$ 3d$^{10}$ 4s$^2$ 4p$^6$ 4d$^{10}$ 4f$^9$ 5s$^2$ 5p$^6$ 6s$^2$
**Valence electrons:** 4f$^9$ 6s$^2$
**Crystal form:** Hexagonal, close packed
**Cross section $\sigma$:** 30 ± 10 barns

# Tl Thallium

81

204.37

IIIA

| 10.81 |
|---|
| B |
| 5 |
| 26.98154 |
| Al |
| 13 |
| 69.72 |
| Ga |
| 31 |
| 114.82 |
| In |
| 49 |
| 204.37 |
| Tl |
| 81 |

**Tálio**
**Thallium**
**Thallium**
**Talio**
**таллий**
**תליום**
鉈 タリウム

**Naturally occurring isotopes:** 205, 203
**Density:** 11.85 g/cm$^3$ (20°C)
**Melting point:** 303.5°C **Boiling point:** 1457 ± 10°C
**Latent heat of fusion:** 20.90 J/g
**Specific heat:** 0.129 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 28 × 10$^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 0.461 w/cm/°C (25°C)
**Electrical resistivity:** 18.0 × 10$^{-6}$ ohm-cm (0°C)
**Ionization potential (1st):** 6.108 eV
**Electron work function** $\phi$: 3.84 eV
**Oxidation potentials:** $Tl \rightarrow Tl^+ + \epsilon = 0.3363$ V
$Tl^+ \rightarrow Tl^{3+} + 2\epsilon = -1.25$ V
**Chemical valence:** *1,* 3
**Electrochemical equivalents:** 7.6250 g/amp-hr
**Ionic radius:** 1.50 Å ($Tl^+$)
**Valence electron potential (−εV):** 9.60
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 6s^2\ 6p^1$
**Valence electrons:** $6s^2\ 6p^1$
**Crystal form:** Hexagonal, close packed
**Cross section** $\sigma$: 3.4 ± 0.5 barns
**Vapor pressure:** 5.33 × 10$^{-6}$ Pa (at melting point)

# Th Thorium

90

232.03807

Actinide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 232.03807 Th 90 | 231.0359 Pa 91 | 238.029 U 92 | 237.0482 Np 93 | 244.06423 Pu 94 | 243.0614 Am 95 | 247.07038 Cm 96 | 247.07032 Bk 97 | 251.07961 Cf 98 | 254.08805 Es 99 |
| 257.09515 Fm 100 | 258 Md 101 | 259 No 102 | 260 Lr 103 | | | | | | |

Tório
Thorium
Thorium
Torio
торий
תוריום
針 トリウム

**Naturally occurring isotope:** 232
**Density:** 11.724 g/cm$^3$ (25°C)
**Melting point:** 1750°C **Boiling point:** 4787°C
**Latent heat of fusion:** 82.93 J/g
**Specific heat:** 0.118 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 12.5 × $10^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 0.540 w/cm/°C (25°C)
**Electrical resistivity:** 13.1 × $10^{-6}$ ohm-cm (25°C)
**Ionization potential (1st):** 6.08 eV
**Electron work function** $\phi$: 3.41 eV
**Oxidation potential:** $Th \rightarrow Th^{4+} + 4\epsilon = 1.899$ V
**Chemical valence:** 3, *4*
**Electrochemical equivalents:** 2.1643 g/amp-hr
**Ionic radius:** 0.972 Å ($Th^{4+}$)
**Valence electron potential (−ε V):** 59.3
**Principal quantum number:** 7
**Principal electron shells:** K L M N O P Q
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 6s^2\ 6p^6\ 6d^2\ 7s^2$
**Valence electrons:** $6d^2\ 7s^2$
**Crystal form:** Cubic, face centered
**Half life:** 1.40 × $10^{10}$ years
**Cross section** $\sigma$: 74 ± 0.1 barns

# Tm Thulium

69

168.9342

Lanthanide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 140.12 Ce 58 | 140.9077 Pr 59 | 144.24 Nd 60 | 144.913 Pm 61 | 150.4 Sm 62 | 151.96 Eu 63 | 157.25 Gd 64 | 158.9254 Tb 65 | 162.50 Dy 66 | 164.9304 Ho 67 |
| 167.26 Er 68 | 168.9342 Tm 69 | 173.04 Yb 70 | 174.97 Lu 71 | | | | | | |

Túlio
Thulium
Thulium
Tulio
тулий
תוליום
銩 ツリウム

**Naturally occurring isotope:** 169
**Density:** 9.321 g/cm$^3$ (25°C)
**Melting point:** 1545 ± 15°C **Boiling point:** 1727°C
**Latent heat of fusion:** 109.0 J/g
**Specific heat:** 0.160 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 11.6 × $10^{-6}$ cm/cm/°C (400°C)
**Thermal conductivity:** 0.169 w/cm/°C (25°C)
**Electrical resistivity:** 79 × $10^{-6}$ ohm-cm (25°C)
**Ionization potential (1st):** 6.1844 eV
**Oxidation potential:** Tm → $Tm^{3+}$ + 3ε = 2.278 V
**Chemical valence:** 2, *3*
**Electrochemical equivalents:** 2.1010 g/amp-hr
**Ionic radius:** 0.869 Å ($Tm^{3+}$)
**Valence electron potential (−εV):** 49.7
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{13}\ 5s^2\ 5p^6\ 6s^2$
**Valence electrons:** $4f^{13}\ 6s^2$
**Crystal form:** Hexagonal, close packed
**Cross section σ:** 115 ± 15 barns
**Vapor pressure:** 4.90 × $10^{-3}$ Pa (at melting point)

# Sn Tin

50

118.69

IVA

| 12.011 |
|---|
| C |
| 6 |
| 28.0855 |
| Si |
| 14 |
| 72.59 |
| Ge |
| 32 |
| 118.69 |
| Sn |
| 50 |
| 207.2 |
| Pb |
| 82 |

**Estanho**
**Etain**
**Zinn**
**Estaño**
**олово**
**בדיל**
**錫 すず**

**Naturally occurring isotopes:** 120, 118, 116, 119, 117, 124, 122, 112, 114, 115
**Density:** 7.298 g/cm$^3$ (25°C)
**Melting point:** 231.9681°C **Boiling point:** 2270°C
**Latent heat of fusion:** 60.67 J/g
**Specific heat:** 0.227 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** $23 \times 10^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 0.668 w/cm/°C (25°C)
**Electrical resistivity:** $11.5 \times 10^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 7.334 eV
**Electron work function $\phi$:** 4.42 eV
**Oxidation potentials:** $Sn \rightarrow Sn^{2+} + 2\epsilon = 0.136$ V
$Sn^{2+} \rightarrow Sn^{4+} + 2\epsilon = -0.15$ V
**Chemical valence:** $-4, -1, 2, \mathit{4}$
**Electrochemical equivalents:** 1.1071 g/amp-hr
**Ionic radius:** 0.690 Å ($Sn^{4+}$)
**Valence electron potential ($-\varepsilon$V):** 83.5
**Principal quantum number:** 5
**Principal electron shells:** K L M N O
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 5s^2\ 5p^2$
**Valence electrons:** $5s^2\ 5p^2$
**Crystal form:** Tetragonal
**Cross section $\sigma$:** $0.63 \pm 0.1$ barns
**Vapor pressure:** $5.78 \times 10^{-21}$ Pa (at melting point)

# Ti Titanium

22

47.90

IVB

| |
|---|
| 47.90<br>Ti<br>22 |
| 91.22<br>Zr<br>40 |
| 178.49<br>Hf<br>72 |
| 104 |

**Titânio**
**Titane**
**Titan**
**Titanio**
**титан**
**טיטניום**
**鈦 チタン**

**Naturally occurring isotopes:** 48, 46, 47, 49, 50
**Density:** 4.507 g/cm$^3$ (20°C)
**Melting point:** 1660 ± 10°C **Boiling point:** 3287°C
**Latent heat of fusion:** 323.4 J/g
**Specific heat:** 0.522 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 8.41 × $10^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 0.219 w/cm/°C (25°C)
**Electrical resistivity:** 42 × $10^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 6.82 eV
**Electron work function** $\phi$**:** 4.33 eV
**Oxidation potential:** $Ti \rightarrow Ti^{2+} + 2\epsilon = 1.628$ V
**Chemical valence:** 1, 2, 3, *4*
**Electrochemical equivalents:** 0.4468 g/amp-hr
**Ionic radius:** 0.605 Å ($Ti^{4+}$)
**Valence electron potential (**$-\varepsilon$**V):** 95.2
**Principal quantum number:** 4
**Principal electron shells:** K L M N
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^2$
**Valence electrons:** $3d^2\ 4s^2$
**Crystal form:** Hexagonal, close packed
**Cross section** $\sigma$**:** 6.1 ± 0.2 barns
**Vapor pressure:** 4.90 × $10^{-1}$ Pa (at melting point)

# W Tungsten

74

183.85

VIB

| 51.996 |
|---|
| Cr |
| 24 |
| 95.94 |
| Mo |
| 42 |
| 183.85 |
| W |
| 74 |
| 106 |

Tungstênio
Tungstène
Wolframz
Tungsteno
вольфрам
וולפרם
鎢 タングステン

**Naturally occurring isotopes:** 184, 186, 182, 183, 180
**Density:** 19.35 g/cm$^3$ (20°C)
**Melting point:** 3410 ± 20°C **Boiling point:** 5660°C
**Latent heat of fusion:** 191.7 J/g
**Specific heat:** 0.125 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 4.6 × $10^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 1.73 w/cm/°C (25°C)
**Electrical resistivity:** 5.65 × $10^{-6}$ ohm-cm (27°C)
**Ionization potential (1st):** 7.98 eV
**Electron work function $\phi$:** 4.55 eV
**Oxidation potential:** $W + 3H_2O \rightarrow WO_3 + 6H^+ + 6\epsilon = 0.09$ V
**Chemical valence:** 2, 3, 4, 5, *6*
**Electrochemical equivalents:** 1.1432 g/amp-hr
**Ionic radius:** 0.62 Å ($W^{6+}$)
**Valence electron potential ($-\varepsilon$V):** 140
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^4\ 6s^2$
**Valence electrons:** $5d^4\ 6s^2$
**Crystal form:** Alpha—cubic, body centered; beta—cubic, face centered
**Cross section $\sigma$:** 18.5 ± 0.5 barns
**Vapor pressure:** 4.27 Pa (at melting point)

# U Uranium

92

238.029

Actinide Series

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 232.03807 Th 90 | 231.0359 Pa 91 | 238.029 U 92 | 237.0482 Np 93 | 244.06423 Pu 94 | 243.0614 Am 95 | 247.07038 Cm 96 | 247.07032 Bk 97 | 251.07961 Cf 98 | 254.08805 Es 99 |
| 257.09515 Fm 100 | 258 Md 101 | 259 No 102 | 260 Lr 103 | | | | | | |

**Urânio**
**Uranium**
**Uran**
**Uranio**
**уран**
**אורניום**
**鈾 ウラニウム**

**Naturally occurring isotopes:** 238, 235, 234
**Density:** 19.04 g/cm$^3$ (25°C)
**Melting point:** 1132.3 ± 0.8°C **Boiling point:** 3818°C
**Latent heat of fusion:** 65.08 J/g
**Specific heat:** 0.1162 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 13.4 × $10^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 0.275 w/cm/°C (25°C)
**Electrical resistivity:** 27 × $10^{-6}$ ohm-cm (25°C)
**Ionization potential (1st):** 6.05 eV
**Electron work function** $\phi$: 3.63 eV
**Oxidation potential:** $U \rightarrow U^{3+} + 3\epsilon = 1.789$ V
**Chemical valence:** 3, 4, 5, *6*
**Electrochemical equivalents:** 1.4801 g/amp-hr
**Ionic radius:** 0.52 Å ($U^{6+}$)
**Valence electron potential (−εV):** 170
**Principal quantum number:** 7
**Principal electron shells:** K L M N O P Q
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 5f^3\ 6s^2\ 6p^6\ 6d^1\ 7s^2$
**Valence electrons:** $5f^3\ 6d^1\ 7s^2$
**Crystal form:** Orthorhombic
**Half life:** 4.51 × $10^9$ years
**Cross section** $\sigma$: 7.595 ± 0.070 barns
**Vapor pressure:** 1.19 × $10^{-6}$ Pa (at melting point)

# Vanadium

23

50.9415

VB

| |
|---|
| 50.9415<br>V<br>23 |
| 92.9064<br>Nb<br>41 |
| 180.9479<br>Ta<br>73 |
| 105 |

Vanádio
Vanadium
Vanadium
Vanadio
ванадий
ונדיום
釩 バナジウム

**Naturally occurring isotopes:** 51, 50
**Density:** 6.11 g/cm$^3$ (18.7°C)
**Melting point:** 1890 ± 10°C **Boiling point:** 3380°C
**Latent heat of fusion:** 345.2 J/g
**Specific heat:** 0.489 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 6.15 × 10$^{-6}$ cm/cm/°C (25°C)
**Thermal conductivity:** 0.307 w/cm/°C (25°C)
**Electrical resistivity:** 24.8 × 10$^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 6.74 eV
**Electron work function $\phi$:** 4.3 eV
**Oxidation potential:** $V \rightarrow V^{2+} + 2\epsilon = 1.186$ V
**Chemical valence:** 2, 3, 4, *5*
**Electrochemical equivalents:** 0.38013 g/amp-hr
**Ionic radius:** 0.59 Å ($V^{5+}$)
**Valence electron potential ($-\varepsilon$V):** 120
**Principal quantum number:** 4
**Principal electron shells:** K L M N
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3\ 4s^2$
**Valence electrons:** $3d^3\ 4s^2$
**Crystal form:** Cubic, body centered
**Cross section $\sigma$:** 5.06 ± 0.06 barns
**Vapor pressure:** 3.06 Pa (at melting point)

# Xe Xenon

54

131.30

O

| |
|---|
| 4.00260 He 2 |
| 20.179 Ne 10 |
| 39.948 Ar 18 |
| 83.80 Kr 36 |
| 131.30 Xe 54 |
| 222.01761 Rn 86 |

Xenônio

Xénon

Xenon

Xenón

ксенон

כסנון

氙 キセノン

**Naturally occurring isotopes:** 132, 129, 131, 134, 136, 130, 128, 124, 126
**Density:** $5.895 \times 10^{-3}$ g/cm$^3$ (20°C)
**Melting point:** −111.9°C **Boiling point:** −107.1 ± 3°C
**Latent heat of fusion:** 17.5 J/g
**Specific heat:** 0.15831 J/g/°C (25°C)
**Thermal conductivity:** 0.514 mw/cm/°C (0°C at 1 atm)
**Ionization potential (1st):** 12.130 eV
**Chemical valence:** 0
**Principal quantum number:** 5
**Principal electron shells:** K L M N O
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 5s^2\ 5p^6$
**Valence electrons:** ($5s^2\ 5p^6$)
**Crystal form:** Cubic, face centered
**Cross section σ:** 24.5 ± 1.0 barns

# Yb Ytterbium

70

173.04

Lanthanide Series

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 140.12 Ce 58 | 140.9077 Pr 59 | 144.24 Nd 60 | 144.913 Pm 61 | 150.4 Sm 62 | 151.96 Eu 63 | 157.25 Gd 64 | 158.9254 Tb 65 | 162.50 Dy 66 | 164.9304 Ho 67 | |
| 167.26 Er 68 | 168.9342 Tm 69 | 173.04 Yb 70 | 174.97 Lu 71 | | | | | | | |

Itérbio
Ytterbium
Ytterbium
Iterbio
иттербий
איטרביום
鐿 イッテルビウム

**Naturally occurring isotopes:** 174, 172, 173, 171, 176, 170, 168
**Density:** 6.965 g/cm$^3$ (25°C)
**Melting point:** 819°C **Boiling point:** 1194°C
**Latent heat of fusion:** 53.23 J/g
**Specific heat:** 0.155 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 29.9 × 10$^6$ cm/cm/°C (25°C)
**Thermal conductivity:** 0.349 w/cm/°C (25°C)
**Electrical resistivity:** 28 × 10$^{-6}$ ohm-cm (25°C)
**Ionization potential (1st):** 6.2539 eV
**Oxidation potential:** Yb → Yb$^{3+}$ + 3$\epsilon$ = 2.267 V
**Chemical valence:** 2, *3*
**Electrochemical equivalents:** 2.1520 g/amp-hr
**Ionic radius:** 0.858 Å (Yb$^{3+}$)
**Valence electron potential (−εV):** 50.3
**Principal quantum number:** 6
**Principal electron shells:** K L M N O P
**Electronic configuration:** 1s$^2$ 2s$^2$ 2p$^6$ 3s$^2$ 3p$^6$ 3d$^{10}$ 4s$^2$ 4p$^6$ 4d$^{10}$ 4f$^{14}$ 5s$^2$ 5p$^6$ 6s$^2$
**Valence electrons:** 4f$^{14}$ 6s$^2$
**Crystal form:** Cubic, face centered
**Cross section σ:** 37 ± 3 barns
**Vapor pressure:** 3.95 × 10$^2$ Pa (at melting point)

# Y Yttrium

39

88.9059

IIIB

| 44.95592 |
|---|
| Sc |
| 21 |
| 88.9059 |
| Y |
| 39 |
| 138.9055 |
| La |
| 57 |
| 227.02777 |
| Ac |
| 89 |

Itrio
Yttrium
Yttrium
Itrio
иттрий
איטריום
釔 イットリウム

**Naturally occurring isotope:** 89
**Density:** 4.469 g/cm$^3$ (25°C)
**Melting point:** 1522°C **Boiling point:** 3338°C
**Latent heat of fusion:** 193.1 J/g
**Specific heat:** 0.298 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** $10.8 \times 10^{-6}$ cm/cm/°C (400°C)
**Thermal conductivity:** 0.172 w/cm/°C (25°C)
**Electrical resistivity:** $57 \times 10^{-6}$ ohm-cm (25°C)
**Ionization potential (1st):** 6.38 eV
**Electron work function $\phi$:** 3.1 eV
**Oxidation potential:** $Y \rightarrow Y^{3+} + 3\epsilon = 2.372$ V
**Chemical valence:** 3
**Electrochemical equivalents:** 1.1057 g/amp-hr
**Ionic radius:** 0.900 Å ($Y^{3+}$)
**Valence electron potential ($-\varepsilon$V):** 48.0
**Principal quantum number:** 5
**Principal electron shells:** K L M N O
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^1\ 5s^2$
**Valence electrons:** $4d^1\ 5s^2$
**Crystal form:** Hexagonal, close packed
**Cross section $\sigma$:** $1.3 \pm 0.1$ barns
**Vapor pressure:** 5.31 Pa (at melting point)

# Zn Zinc

30

65.38

IIB

| 65 38 |
|---|
| Zn |
| 30 |
| 112 41 |
| Cd |
| 48 |
| 200 59 |
| Hg |
| 80 |

**Zinco**
**Zinc**
**Zink**
**Zinc**
**цинк**
**אבץ**
鋅 亜鉛

**Naturally occurring isotopes:** 64, 66, 68, 67, 70
**Density:** 7.133 g/cm$^3$ (25°C)
**Melting point:** 419.58°C **Boiling point:** 907°C
**Latent heat of fusion:** 113.0 J/g
**Specific heat:** 0.388 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 39.7 $\times$ $10^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 1.16 w/cm/°C (25°C)
**Electrical resistivity:** 5.916 $\times$ $10^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 9.394 eV
**Electron work function $\phi$:** 4.33 eV
**Oxidation potential:** $Zn \rightarrow Zn^{2+} + 2\epsilon = 0.7628$ V
**Chemical valence:** 2
**Electrochemical equivalents:** 1.220 g/amp-hr
**Ionic radius:** 0.740 Å ($Zn^{2+}$)
**Valence electron potential ($-\varepsilon$V):** 38.9
**Principal quantum number:** 4
**Principal electron shells:** K L M N
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2$
**Valence electrons:** $4s^2$
**Crystal form:** Hexagonal, close packed
**Cross section $\sigma$:** 1.10 $\pm$ 0.04 barns
**Vapor pressure:** 19.2 Pa (at melting point)

# Zr Zirconium

40

91.22

IVB

| |
|---|
| 47.90<br>Ti<br>22 |
| 91.22<br>Zr<br>40 |
| 178.49<br>Hf<br>72 |
| 104 |

Zircônio
Zirconium
Zirkonium
Zirconio
цирконий
צירקוניום
鉿 ジルコニウム

**Naturally occurring isotopes:** 90, 94, 92, 91, 96
**Density:** 6.506 g/cm$^3$ (20°C)
**Melting point:** 1852 ± 2°C **Boiling point:** 4377°C
**Latent heat of fusion:** 251.2 J/g
**Specific heat:** 0.278 J/g/°C (25°C)
**Coefficient of lineal thermal expansion:** 5.85 × 10$^{-6}$ cm/cm/°C (20°C)
**Thermal conductivity:** 0.227 w/cm/°C (27°C)
**Electrical resistivity:** 40 × 10$^{-6}$ ohm-cm (20°C)
**Ionization potential (1st):** 6.84 eV
**Electron work function $\phi$:** 4.05 eV
**Oxidation potential:** $Zr \rightarrow Zr^{4+} + 4\epsilon = 1.529$ V
**Chemical valence:** 1, 2, 3, *4*
**Electrochemical equivalents:** 0.8509 g/amp-hr
**Ionic radius:** 0.72 Å ($Zr^{4+}$)
**Valence electron potential ($-\varepsilon$V):** 80
**Principal quantum number:** 5
**Principal electron shells:** K L M N O
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^2\ 5s^2$
**Valence electrons:** $4d^2\ 5s^2$
**Crystal form:** Hexagonal, close packed
**Cross section $\sigma$:** 0.182 ± 0.005 barns
**Vapor pressure:** 1.68 × 10$^{-3}$ Pa (at melting point)

# Element 104 Kurchatovium Rutherfordium

104

261

IVB

| |
|---|
| 47.90<br>Ti<br>22 |
| 91.22<br>Zr<br>40 |
| 178.49<br>Hf<br>72 |
| 104 |

**Naturally occurring isotopes:** None
**Chemical valence:** 4
**Principal quantum number:** 7
**Principal electron shells:** K L M N O P Q
**Electronic configuration:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 5f^{14}\ 6s^2\ 6p^6\ 6d^2\ 7s^2$
**Valence electrons:** $6d^2\ 7s^2$
**Half life:** ~65 seconds

# Element 105 Nielsbohrium Hahnium

105

(262)

VB

| |
|---|
| 50.9415<br>V<br>23 |
| 92.9064<br>Nb<br>41 |
| 180.9479<br>Ta<br>73 |
| 105 |

**Naturally occurring isotopes:** None
**Chemical valence:** (5)
**Principal quantum number:** 7
**Principal electron shells:** K L M N O P Q
**Half life:** ~40 seconds

# Element
# 106

106

(263)

VIB

| |
|---|
| 51.996<br>Cr<br>24 |
| 95.94<br>Mo<br>42 |
| 183.85<br>W<br>74 |
| 106 |

**Naturally occurring isotopes:** None
**Chemical valence:** (6)
**Principal quantum number:** 7
**Principal electron shells:** K L M N O P Q
**Half life:** ~1 second

# Element
# 107

# 107
# (262)

VIIB

| 54.9380 |
| --- |
| Mn |
| 25 |
| 96.906 |
| Tc |
| 43 |
| 186.2 |
| Re |
| 75 |
| 107 |

**Naturally occurring isotopes:** None
**Chemical valence:** (7)
**Principal quantum number:** 7
**Principal electron shells:** K L M N O P Q

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Helvetica Chimica Acta
Inorganic Chemistry
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Journal of Applied Physics
Journal of Chemical and Engineering Data
Journal of Chemical Education
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Journal of Inorganic and Nuclear Chemistry
Journal of Less-Common Metals
Journal of Physical and Chemical Reference Data
Journal of Physical Chemistry
Journal of Physics and Chemistry of Solids
Journal of Solid State Chemistry
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Journal of the Electrochemical Society
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